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The Magazine of Space Exploration

October 1989

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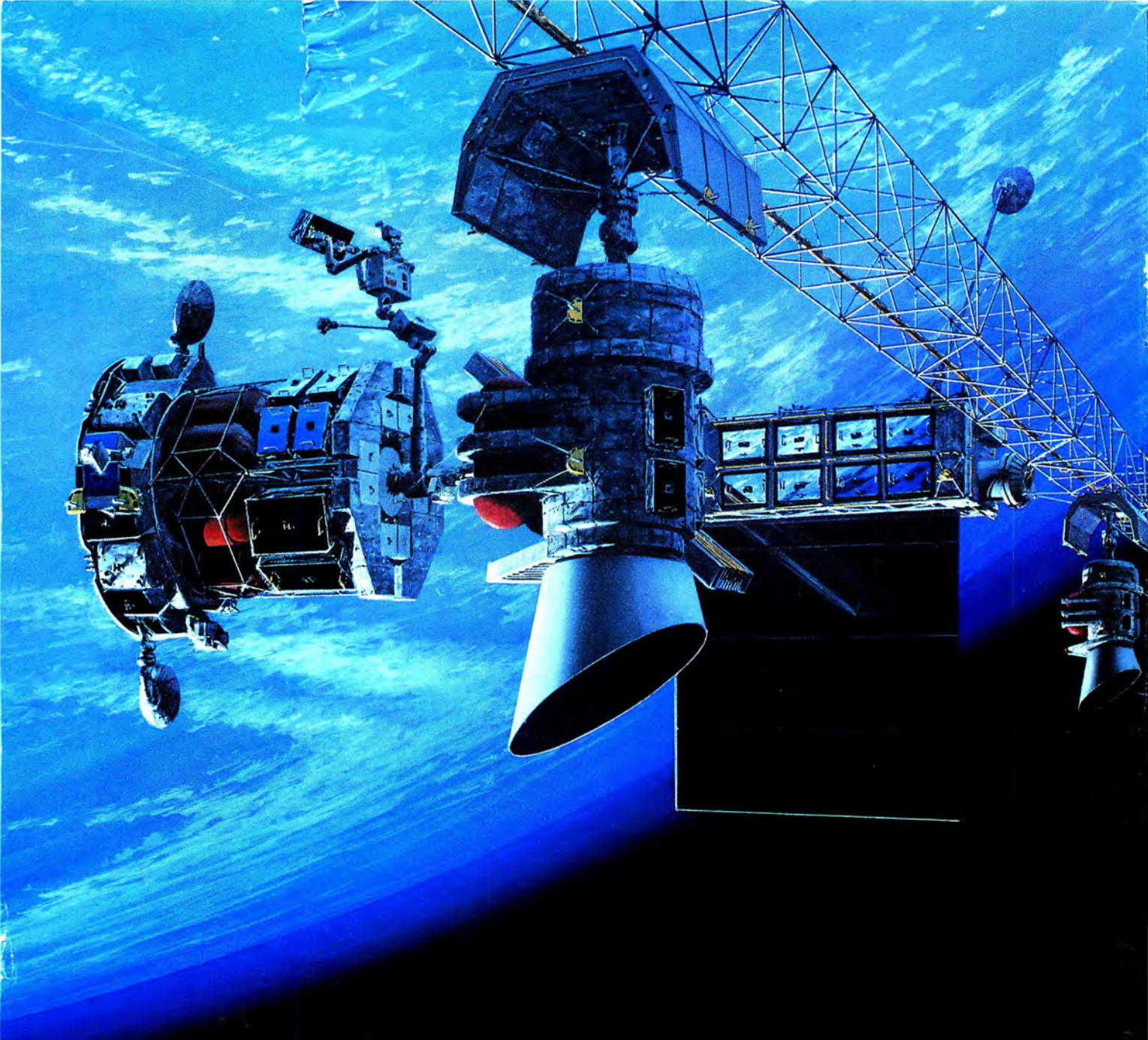

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September/October 1989
Volume 2, Number 5

If we can't pay for it, we can't do it. That sobering truth has politicians, bureaucrats and entrepreneurs all scratching their heads, searching for new ways to beat the high cost of space exploration. See the stories beginning on page 18. (Cover art by Steve Johnson.)

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FROM THE PUBLISHER

Can we afford the dream?

The answer to the question on this month's cover is, of course, yes. But what's the business plan? That's the *real* question.

In a society that has dreamed up pyramid schemes, lotteries, blind pools and junk bonds, it seems to me that we ought to be able to come up with creative financing concepts for the space program.

As the story goes, Queen Isabella offered to sell her crown jewels to pay for Columbus' first voyage. It turned out she didn't need to, but it wouldn't have been a bad trade. You can only look at jewels so much.

Do we still have to sell our jewels to explore new worlds? Or is there another way? I do know that problems tend to get solved when people of intelligence direct their attention to solving them. So I'd like to pose this question to the Final Frontier Advisory Committee—you readers:

How can we finance our future in space?

This isn't a contest. There are no prizes. But if you send us new and interesting ideas, we'll publish them. Who knows? Maybe one of you has figured it all out, and nobody's bothered to ask you the question.

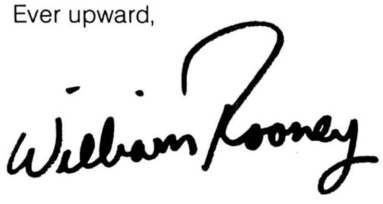
When the U.S. Olympic Committee got concerned about the declining number of American medalists, they looked to the private sector for aggressive, creative ideas. It makes sense. In the competitive business world, only the quick, strong and smart survive. And that's where our "Daring Dozen" of the space business (page 25) come in. If they aren't all yet success stories, we expect that they will be someday.

For the time being, though, we have to rely on governments to pay for our dreams. President Bush's call for a reinvigorated space effort on the 20th anniversary of the first Moon landing was encouraging. Now it's up to him, the Congress and the rest of us to follow through. After all, the best way to get our tax money's worth is to give our scientists and engineers something to *do*.

How can we spend money on space exploration when there are problems here on Earth? I've never thought it was an either/or proposition. You have to look out as well as in, and a perfect society has never been a prerequisite for exploration. By one estimate, the space program puts seven dollars back into the economy for every tax dollar spent. But its real value to civilization is *long-term*—the kind of value that doesn't show up in the quarterly ledger books. As historian Daniel Boorstin remarked during the recent Apollo anniversary, the most worthwhile things in life—love and children, for example—cannot be shown to be "cost-effective."

Moving humankind out into space won't come cheap. But let's not use that as an excuse to stop trying to find a better way.

Ever upward,



William Rooney
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Let's just call it a gift from this generation to the next.

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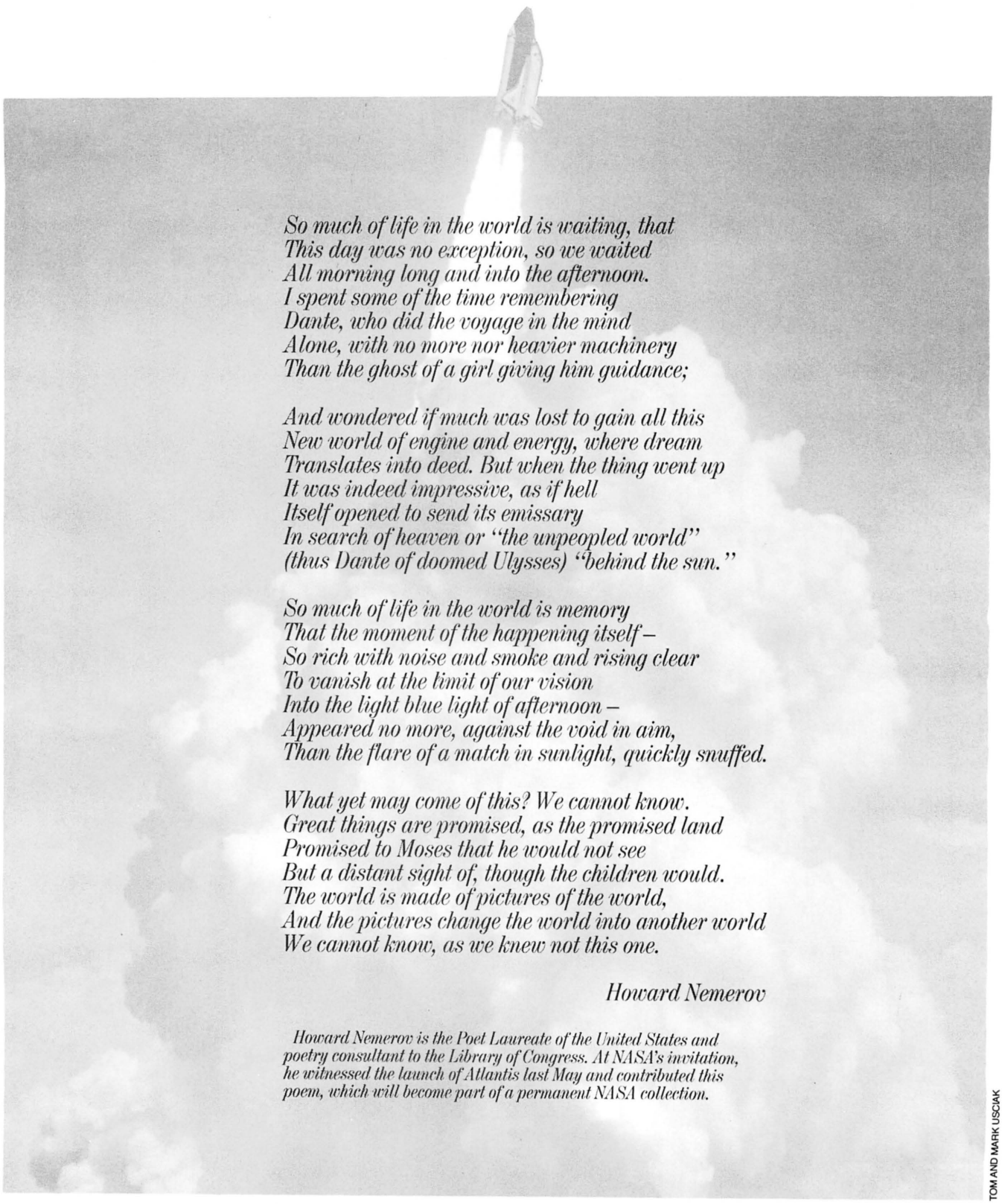
THE OBSERVATORY

Witnessing the Launch of the Shuttle Atlantis



So much of life in the world is waiting, that
This day was no exception, so we waited
All morning long and into the afternoon.
I spent some of the time remembering
Dante, who did the voyage in the mind
Alone, with no more nor heavier machinery
Than the ghost of a girl giving him guidance;

And wondered if much was lost to gain all this
New world of engine and energy, where dream
Translates into deed. But when the thing went up
It was indeed impressive, as if hell
Itself opened to send its emissary
In search of heaven or "the unpeopled world"
(thus Dante of doomed Ulysses) "behind the sun."

So much of life in the world is memory
That the moment of the happening itself –
So rich with noise and smoke and rising clear
To vanish at the limit of our vision
Into the light blue light of afternoon –
Appeared no more, against the void in aim,
Than the flare of a match in sunlight, quickly snuffed.

What yet may come of this? We cannot know.
Great things are promised, as the promised land
Promised to Moses that he would not see
But a distant sight of, though the children would.
The world is made of pictures of the world,
And the pictures change the world into another world
We cannot know, as we knew not this one.

Howard Nemerov

Howard Nemerov is the Poet Laureate of the United States and poetry consultant to the Library of Congress. At NASA's invitation, he witnessed the launch of Atlantis last May and contributed this poem, which will become part of a permanent NASA collection.

TOM AND MARK USCIAK

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LETTERS

TOM R. GARRETT

Be Prepared

In looking at the February article on the next ten years of space exploration, I was enraged by the one major item that it excluded: a manned mission to Mars!

Needless to say, a manned mission to Mars before the end of the century is highly unlikely, thanks to the major cuts in the NASA budget during the past two decades. But even if a manned Mars mission will never be undertaken by 1998, at least some aspect of that particular mission should be achieved by then. Shouldn't the Mars-bound craft be under construction by 1998? Shouldn't artificial gravity and artificial biospheres be perfected by 1998? If these possibilities will never be realized nine years from now, then how can a manned mission to Mars be accomplished within the forseeable future?

Yul U. Tolbert
Detroit, Michigan

We agree–that's why a 1998 Mars sample return mission made our list of space highlights of the next decade. And you're right, if we don't get started now on developing the technology, we won't be ready to go to Mars in any forseeable future.–Editor

Condescending

In his review of *The Soviet Manned Space Program,* (June) William Barton commented on the "condescending style of some American writers who treat the Soviet [space] program in a derogatory way, focusing only on problems and errors." Mr. Barton confuses the critical style of American writers, who also focus on the problems and errors of NASA operations, with "Soviet bashing."

In comparing the first U.S. space shuttle test flight, which was manned, to the unmanned test flight of the Soviet Buran shuttle, Alexander Dunayev, director of the Soviet space agency Glavkosmos, issued the following sermonette: "In the development of manned space flights, priority in the USSR is given, first of all, to crew safety. Therefore, the first flight of a new spacecraft is always automatically controlled. This is the basic difference between the Soviet program and the U.S. one, and we shall always adhere to it."

In a "condescending" and "derogatory" manner, Dunayev implies that crew safety is not a priority with NASA's space shuttle flights. If Mr. Barton reviewed a Soviet writer's account of the U.S. space program, he would detect the same "condescending" attitude toward their rival.

Sam Ricks
Philadelphia, Pennsylvania

One for All

I began to read Final Frontier recently, and I must say that your magazine has done its best in announcing space research and exploration. I was staggered by the fact that in the U.S. space exploration has such good publicity! We haven't anything like your magazine.

The April special issue was very interesting. I read the "Roads to Mars" article with great interest, and completely support all the ideas and proposals. There is no doubt that there will be a manned expedition to Mars in the beginning of the next century, and the main problem now is coordinating the efforts of the USSR, the USA, ESA and other space countries in planning the Mars mission. It may be the best objective of mankind, instead of [an] arms race.

I'm a member of SEDS, and our chapter perhaps will receive your magazine. But it will be one magazine for the group of people. *Vladislav Stolyarov*
Kazan, USSR

FINAL FRONTIER welcomes your letters. Send them c/o Letters to the Editor, FINAL FRONTIER, P.O. Box 11519, Washington, D.C. 20008. Please type your correspondence and limit the length to 150 words.

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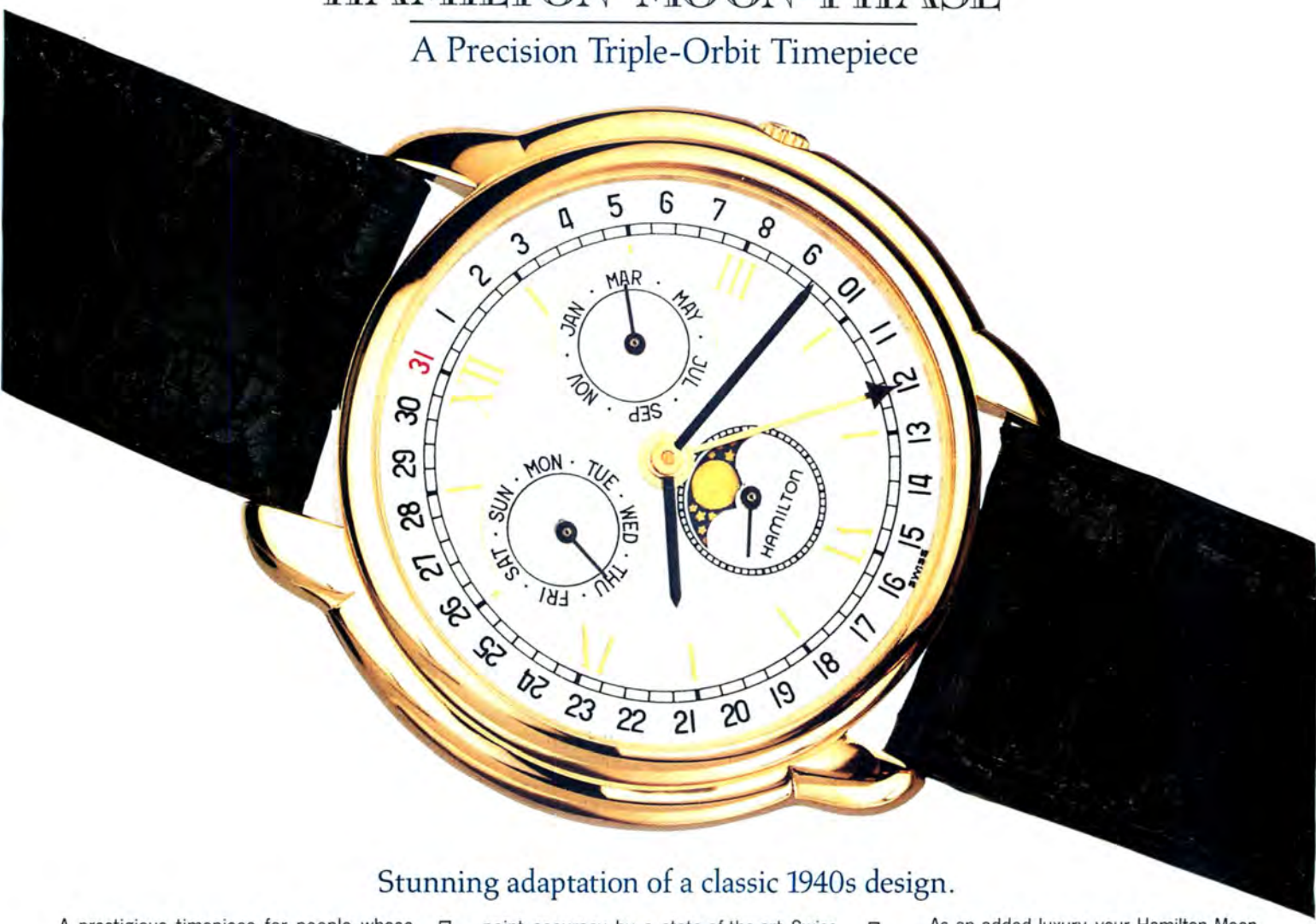

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EARTHLY PURSUITS

Crimebusters

Who ya gonna call? Dial N-A-S-A

▼ ▼ ▼

By Anene Tressler-Hauschultz

In the summer's smash-hit movie *Batman*, Jack Nicholson, a.k.a. the Joker, asks longingly, "Where does he get those wonderful toys?" Even Joker might be surprised that some of the gee-whiz crimebusting tools of the '80s are actually spinoffs of NASA research, available to local governments and the private sector at little or no cost.

For example, imprinted serial numbers are a widely accepted means of identifying and (hopefully) protecting goods from theft. But whether it's a Corvette engine or a handgun, these marks are often erased by thieves who file them down.

In the past, crime labs used a chemical etching technique to recover missing I.D. numbers. While effective, it caused metal corrosion and required a lot of time to prepare. But as part of its research into the problem of pitting that occurs in metal materials in the atmosphere—a phenomenon called "cavitation"—NASA developed a restoration process that eliminates the use of corrosive chemicals. A metal object is immersed in water, with a probe positioned above it. Ultrasonic energy is then applied, causing the probe to vibrate rapidly; the resulting vapor bubbles pit the area where the serial number was stamped.

"Even though the metal looks smooth, it retains a memory of the stamp dye," explains Steven Riddlebaugh of NASA's Lewis Research Center in Cleveland.

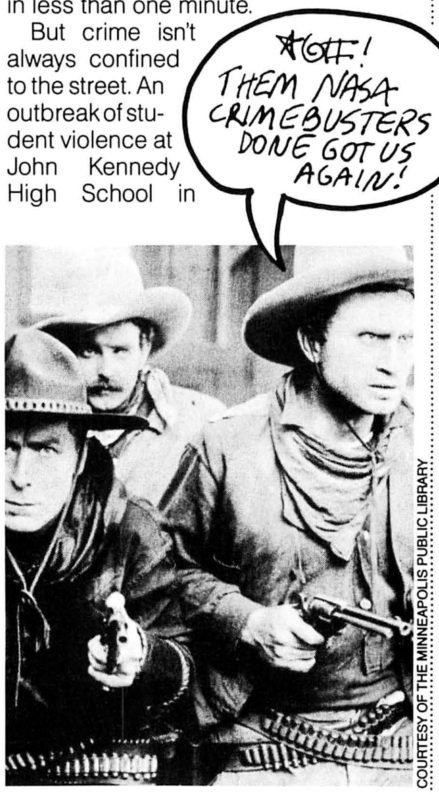
Computer enhancement processes used to improve pictures transmitted from space also can be used to "bring back" signatures and other writing on documents after the writing has been erased or has deteriorated with time. And art thieves beware: NASA has enhancement techniques that can identify the presence of more than one image on a painting. The procedure can even separate the images, yielding reliable pictures of whatever's underneath the surface of a painting.

Another crimebusting device derives from the safety net placed below workers who build space shuttle orbiters in assembly buildings. Bill Kirkland, president of West Coast Netting, reasoned that a web strong enough to break a worker's fall from a high place might have an application for police departments, whose officers often must restrain violent suspects.

The outgrowth of Kirkland's idea, "Capture Net," offers an important alternative to the use of deadly force in apprehending criminals. A three-man team uses the net in conjunction with an ammonium phosphate-base fire extinguisher, which serves as a distraction so officers can get close enough to cast the net. An important advantage of the Capture Net system, notes Kirkland, is that it can be assembled and deployed in less than one minute.

But crime isn't always confined to the street. An outbreak of student violence at John Kennedy High School in Sacramento, California, prompted the school's principal to seek NASA's assistance in developing an alarm system. So the space agency came up with the SCAN (Silent Communications Alarm Network) pen, which consists of a pen-shaped signaling device and a system of receivers interconnected to a constantly monitored master console. A teacher wears the pen in a shirt pocket or as a necklace; if trouble develops, he or she simply presses a clasp, sending an ultrasonic signal to one of the receivers, strategically placed for best reception. The receiver then converts the silent tone to electrical energy and transmits the signal to the master console, setting off an audio alarm and activating a console light that indicates the location of the emergency.

The SCAN system's reliability and ease of operation have led to its installation in senior citizen apartment complexes, juvenile homes and correctional institutions. A similar concept inspired the "Remote Alert Communications System," a pocket-sized tone-modulated FM transmitter that provides a one-way communications link from a police officer in the field to his dispatcher, using the patrol car as a radio relay station.



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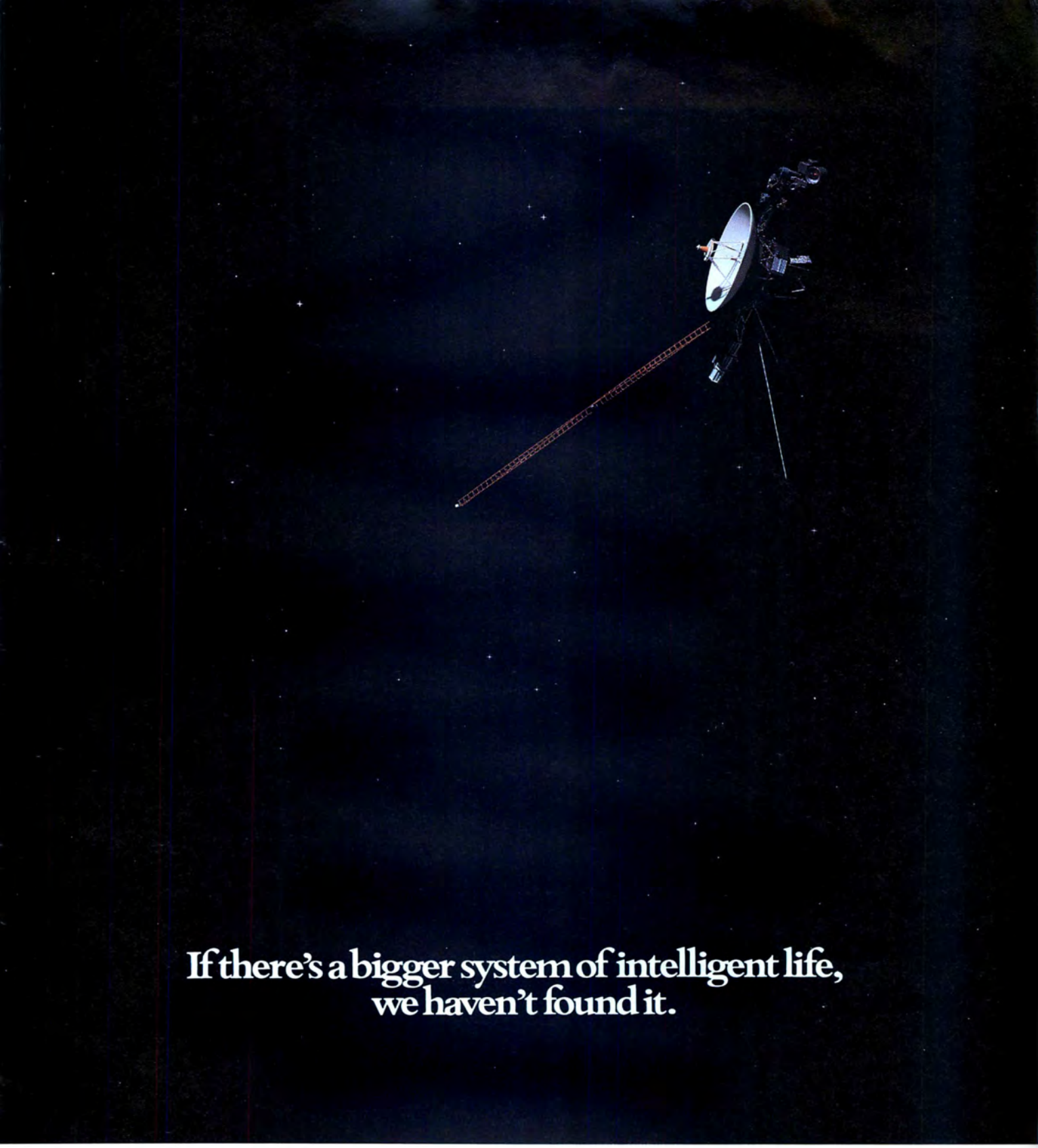
Law enforcement officers use NASA technology in the air as well. A stabilization platform for helicopters, developed at the Jet Propulsion Laboratory, has been used by the Pasadena Police Department to help keep its searchlights trained on fleeing suspects below. And the police department in Huntington Beach, California, reduces fatigue in its helicopter pilots with a spinoff originally developed at NASA's Ames Research Center. Thick pads of "memory foam," installed in the department's helicopters, evenly distribute body weight and pressure over the entire contact area. The result: officers are able to stay aloft for longer periods of surveillance.

Watching and hunting down the Joker and his felonious deck of cards has never been easier than in the space age. With the help of a few well-chosen spinoffs, crimebusters may still have the last laugh. □



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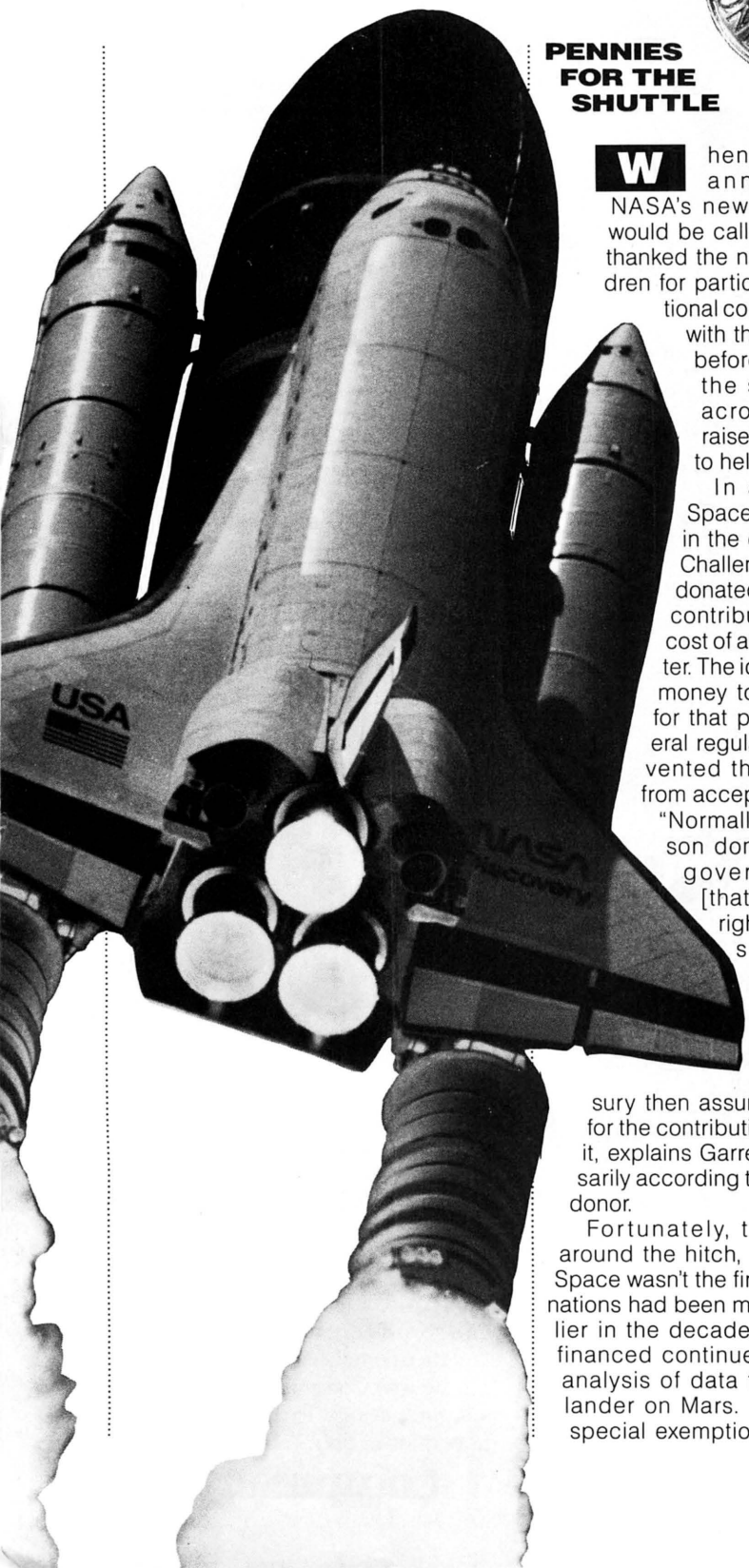


PENNIES FOR THE SHUTTLE

When President Bush announced that NASA's new shuttle orbiter would be called Endeavour, he thanked the nation's schoolchildren for participating in the national contest that came up with the name. But even before they christened the spaceliner, kids across America had raised nearly $300,000 to help build it.

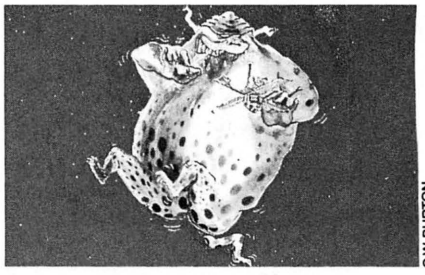
In a "Pennies for Space" drive that began in the days following the Challenger disaster, kids donated their change as contributions toward the cost of a replacement orbiter. The idea was to give the money to NASA expressly for that purpose—but federal regulations almost prevented the space agency from accepting the funds.

"Normally, anytime a person donates money to a government agency, [that] agency gives it right to the U.S. Treasury," says Dave Garrett, a spokesperson at NASA headquarters in Washington, D.C. The treasury then assumes responsibility for the contribution and distributes it, explains Garrett, but not necessarily according to the wishes of the donor.

Fortunately, there was a way around the hitch, since Pennies for Space wasn't the first time private donations had been made to NASA. Earlier in the decade, the Viking Fund financed continued collection and analysis of data from the Viking 1 lander on Mars. NASA received a special exemption from Congress, which permitted the space agency to use the Viking Fund for that purpose. In the summer of 1987, Congress passed similar legislation allowing NASA to apply the children's offering of $290,127 toward Endeavour's $1.3 billion cost.

So the next time someone complains about the price of the space program, tell 'em you know just what to do with their spare change....

—Joseph Baneth Allen



G.W. BURTON

The Ghoul, as seen by a JPL artist.

THE GREAT GALACTIC GHOUL

The twin failures of the Fobos 1 and Fobos 2 Mars-bound spacecraft earlier this year left scientists and engineers wondering how half a billion rubles' worth of the Soviet Union's most sophisticated space equipment could break down without warning. According to the folklore of the space age, there is a simple explanation: Chalk up two more victims for the Great Galactic Ghoul.

The legend of the Ghoul began in July 1969, when NASA's Mariner 7 probe suddenly went dead enroute to Mars. Seven hours later it revived, but it was on a slightly different course and its telemetry capacity was mysteriously reduced.

Time reporter Don Neff, who was covering the mission, recalled that two prior Soviet probes had broken down on the way to Mars, and that NASA's own Mariner 4 had experienced control problems four years earlier. He humorously suggested that some cosmic entity was jealously guarding the road to the Red Planet. In Neff's scenario,

this "Great Galactic Ghoul" had eaten the Soviet craft...bitten off a chunk of Mariner 4...and had spit out Mariner 7 because he (she? *it*?) hadn't liked the taste.

The Ghoul soon developed a loyal tongue-in-cheek following at the Jet Propulsion Laboratory in Pasadena, California, where most American deep space probes are controlled and monitored. So it was natural that in 1971, when Mariner 9 regained its bearings after inexplicably breaking its lock on a navigation star, one happy NASA official exulted, "The Ghoul has been foiled!"

Not so fortunate were two Soviet spacecraft that dared to approach Mars two years later. One sailed helplessly past the planet when its retrorockets failed. Another probe, intended for a landing, lost all communications and also missed Mars.

The Ghoul—or a close relative—operates nearer to home as well. Earth-orbiting satellites occasionally suffer transient equipment failures or shut themselves down for no apparent reason. NASA's Pegasus 1 satellite, turned off in 1975, came *back* to life two years later, sending engineers scurrying for old manuals to compose a new switch-off code. ("Maybe a stake through its heart would help," one commented.)

As for the derelict Fobos 2, supernatural help is on the way. Israeli psychic Uri Geller has announced that he's using his mental powers to revitalize the probe. Somewhere deep in space, the psyche of a magician is battling a galactic ghoul for the soul of a dead robot. Who says space exploration has become dehumanized?

—*James E. Oberg*

DAN PICASSO

THE RAIN IN SPAIN HELPS A SPACESICK BRAIN

If two NASA-sponsored researchers are right, Professor Henry Higgins might have been the perfect doctor to have onboard an orbiting spacecraft.

Robert Stern and Kenneth Koch at Penn State University have found that space sickness, which results from a sensory mismatch, can be avoided by executing a simple mental task such as identifying the nouns in the following sentence: A cat is an animal who likes to eat mice and climb trees.

To test their hypothesis, Stern and Koch simulated an environment that causes the symptoms associated with space sickness. They constructed a rotating cylinder with black horizontal stripes painted on a white interior. Sitting inside the moving drum, a test subject is overcome by the sensation that he or she is moving, and that the drum is standing still. The illusion, called "vection," causes the subject to experience a sensory conflict similar to that which brings on space motion sickness.

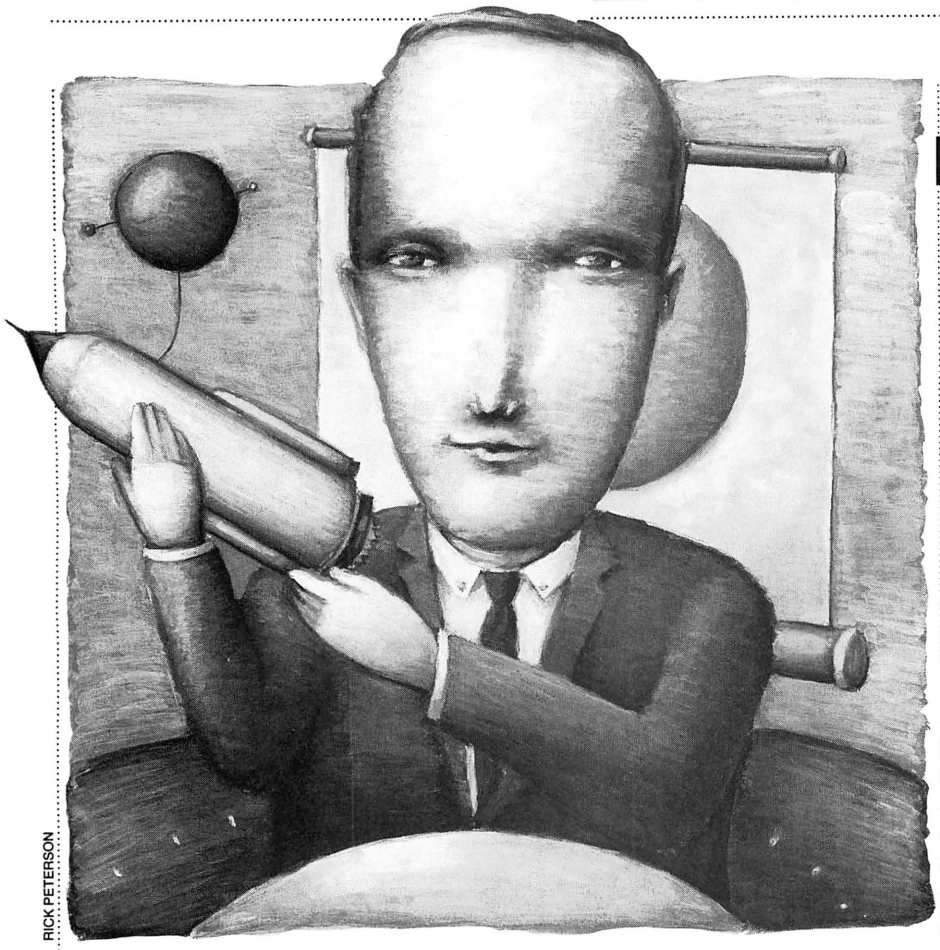
Vection can't be controlled by an individual no matter how much willpower he or she has. Even scientist-astronaut Bill Thornton, a space sickness expert who has a cast-iron stomach in NASA simulators, developed symptoms in the vection drum.

Prior to an experiment run, the Penn State researchers tape three electrodes to the skin above a volunteer's stomach to measure gastric activity. Once the drum begins to rotate, the subject is asked to do basic math or grammar problems. The tests done by Stern and Koch demonstrate decreased stomach awareness in subjects who perform such simple tasks.

Stern and Koch, whose experiments have been funded by NASA for three years, are still trying to discover why problem-solving appears to be an effective defense against space sickness. "It may be that if you don't think about your queasy stomach, it prevents positive biofeedback and keeps you from being sick," says Stern.

—*Joseph Baneth Allen*

NOTES FROM EARTH



RICK PETERSON

ARE YOU LISTENING, DONALD TRUMP?

What do a Coca-Cola sign and Mars have in common? More than the color red, if one entrepreneur has his way.

David Gump, the founder and former publisher of the biweekly Space Business News, would like to see the Coke logo (along with the NBC peacock, the big blue IBM, Apple's apple and other logos) plastered all over a privately financed, manned spacecraft headed for Mars.

"We've come to the point where we have to realize the government just isn't going to get the job done," Gump says.

He notes that 28 years after the Wright brothers flew the first manned aircraft, commercial airline flights with dozens of passengers were routine. But 28 years after Yuri Gagarin's first space lap around the globe, space travel is still reserved for a select group of government employees.

Gump says the private sector solution lies not in the efforts and money of a monolithic scientific institution, but in the mass-market appeal of a manned mission to Mars. Under Gump's proposal, 10 to 14 people with diverse backgrounds from around the world would be sent to Mars in a bare-bones spacecraft, on a two- or three-year mission costing about $6 billion. That's about one-tenth the cost of the deluxe version NASA is now considering.

Funding for the mission would come from several sources: $2 billion from the sale of global television rights to live broadcasts from the spacecraft (CBS paid $1.1 billion for four years of World Series and playoff games, Gump points out); $2 billion from corporate sponsorships *a la* "The official camera of the Independent Mars Mission!"; and $2 billion from passenger fees charged to four countries for the right to send one space traveler each.

Of course, the ultimate success of the mission would depend on everyone returning home safely. "You wouldn't want your first passengers to die," says Gump. "That would be very bad P.R." *— W. Dan Leonard*

SIGNIFICANT DELAYS

A young man grips two joysticks and stares intently into a video screen, where a one-armed robot slowly roams across the lunar landscape. With the left joystick, he steers his robot up to a collection of barrels and crates. With the right, he lifts the robot's arm and opens its gripper. The objective is to pick up the barrels and crates and place them neatly on a platform as quickly as possible.

Okay, so it's not exactly the latest rage from Nintendo. But for anyone who has tried it, it's made even more exciting by its legitimate scientific purpose: Building a database of performance times for the various robotic maneuvers needed to construct a lunar base by remote control from Earth.

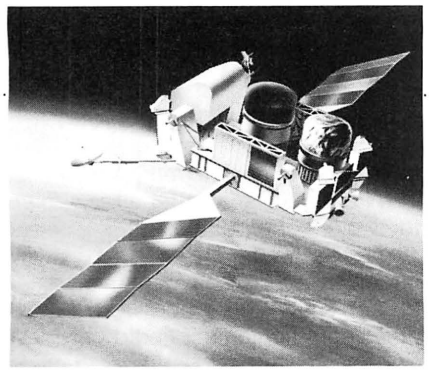
Rob Lewis, chairman of the teleoperations group of the Space Studies Institute in Princeton, New Jersey, says there are plenty of studies of robotic operations in real time, but none of them take into account the three second delay needed for an earthbound operator to send a command to the Moon and receive back a video image of the robot executing the instruction. So Lewis volunteered to do something about it.

"I want to know the number of moves it takes to complete each maneuver and how long it takes with the delay. So when someone comes along later with plans to build a lunar base by teleoperations, they can plan exactly how long it will take," Lewis says.

Using his own money and time, Lewis built the eight-foot mock-up of the lunar surface and installed three video cameras to show the 12-inch robot at work. A black cloth draped over aluminum tubing hides the miniature lunar construction site from the nearby operator's view. With a push of a button the operator can choose which of the three delayed images to display on the screen.

Currently, Lewis is only demonstrating his teleoperations system to enthusiastic crowds at space conferences. In the future, he plans to conduct a full-scale study using ordinary college students and extraordinarily coordinated people as experimental teleoperators.

—W. Dan Leonard



No Nukes: NASA is reprogramming the Gamma Ray Observatory to avoid false readings from Soviet space reactors.

GRO-ING PROBLEM

NASA scientists are scrambling to make changes in the planned Gamma Ray Observatory to compensate for bursts of radiation that do not originate in the heavens. The GRO, slated to be launched next year, will have to contend with gamma rays that originate in nuclear-powered Soviet satellites.

The $500 million GRO is designed to study both intermittent and steady sources of gamma rays. The craft will spend several years orbiting the Earth, first creating a gamma ray map of the entire sky and then concentrating on neutron stars and other sources of gamma ray bursts. Gamma rays are of particular interest to astronomers because they indicate the presence of nuclear fission, and scientists hope to use the satellite to gain insights into the origin and evolution of the universe.

But the presence of orbiting Soviet nuclear satellites, which American officials believe are used to monitor ship movements, threatens to throw a radioactive monkey wrench into the GRO program by creating false alarms.

The uranium inside the Soviet satellites emits gamma rays directly and also produces charged particles as the rays pass through the spacecraft, leaving a trail of positrons and electrons in its wake, says Arthur Reetz, NASA's GRO program manager. "When they interact with our spacecraft materials, they create gamma rays right in the vicinity of our detectors," Reetz explains. "It's much like the light pollution that some of the astronomical observatories are experiencing on the ground."

The space agency is taking a two-pronged approach to avoiding false measurements. One effort involves telling the satellite to disregard readings in certain parts of the Earth's gravitational field that are likely to trap the charged particles. The second approach makes software changes that will allow the GRO to discriminate between a natural gamma ray burst and radiation from a satellite, which is typically accompanied by a sharp increase in charged particles.

The $200,000 effort should be completed well before the 34,500-pound Gamma Ray Observatory—the heaviest automated satellite ever—is lifted into Earth orbit next June.

—Philip Bulman

HEADS UP

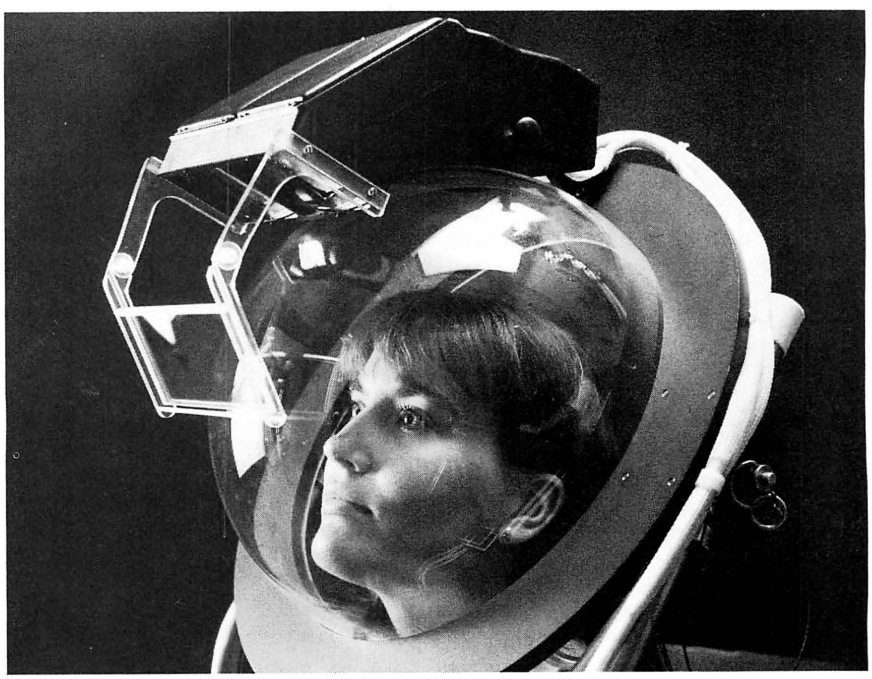
When astronauts Pinky Nelson and James ("Ox") Van Hoften repaired the Solar Max satellite during a space shuttle mission in April 1984, they'd spent six months training for the task. But onboard the international space station Freedom, with as many as three spacewalks per week on the schedule, that amount of training won't be possible for any single job. That's where a helmet-mounted display (HMD) being tested at NASA's Johnson Space Center comes in.

Suppose you're outside the station assembling a strut and you need to refer to a diagram. Just call up the schematic you've programmed into your helmet display, and it appears a few degrees above your line of vision. All you need to do is glance up from your work as you would from a keyboard to a computer screen.

The HMD works something like the "heads-up" displays used by Air Force fighter pilots, says Johnson's Jose Marmolejo. But the readouts actually appear inside the helmet, reflected off holographic optical elements—very thin film deposits sandwiched between the exterior visor and the interior pressure helmet.

During a spacewalk you can call up data (how much time has elapsed, how much fuel is left in your maneuvering unit), graphics or even video images. You can receive material radioed up from Mission Control or from inside Freedom. You can adjust the display so that you don't have to refocus your eyes as you look from your work to your data or diagram. And you can look past the transparent display to see outside. The idea, says Marmolejo, is to keep an astronaut's hands free for work. At just the touch of your finger or the sound of your voice, the HMD will provide all the information you need—right before your eyes.

—Ray Spangenburg/Diane Moser



Space station astronauts will have their hands free, thanks to a newly developed helmet-mounted display.

BBDO WORLDWIDE/DETROIT

Tapping audience interest: Chrysler's Dodge Spirit ad

SPACE FOR SALES

Now that the United States is back in the business of launching spacecraft, advertisers are once again turning to space as a theme for selling a whole galaxy of products and services.

Immediately after the Challenger tragedy, Madison Avenue backed off from using ad themes related to the space program. But since the shuttle got back on track with Discovery's launch a year ago, sponsors and ad agencies have been returning to the cosmos to tap audience interest. A recent TV spot for Glad Drawstring trash bags, for example, shows ersatz shuttle astronauts using the bags to stash orbiting junk. The Chrysler Corporation kicked off its own high-profile campaign during last January's Super Bowl. In the ad, a throng assembled to watch Discovery land in the California desert turns away from the touchdown to ogle a shiny new Dodge Spirit ES driving through the parking area.

Jay Kuhnie, national advertising manager for Dodge cars, says that the shuttle, representing a home-grown, high-tech mode of transportation, was suggested by the BBDO Worldwide ad agency to communicate Dodge's enthusiasm for the engineering advances used in designing the Spirit. This subtly patriotic theme apparently succeeded; Kuhnie notes that viewer reaction and sales figures have been favorable.

Print advertisements also are being designed with space in mind. An orbiting satellite is the dominant image in Consolidated Freightway's full-page magazine ads, and the state of Florida led a seven-page spread in *Forbes* with a shuttle launch photo. Even real estate developers have gotten into the act: Orchard Properties of San Jose, California uses the shuttle to signify "developments in our developments."

Advertising trends often reflect the mood and interests of the nation at large. If that's true in this case, the resurgence of cosmic themes may be good news for advocates of an expanded American commitment to space exploration. —*Mary O'Neill*

THIS WAY TO THE EDGE OF THE UNIVERSE

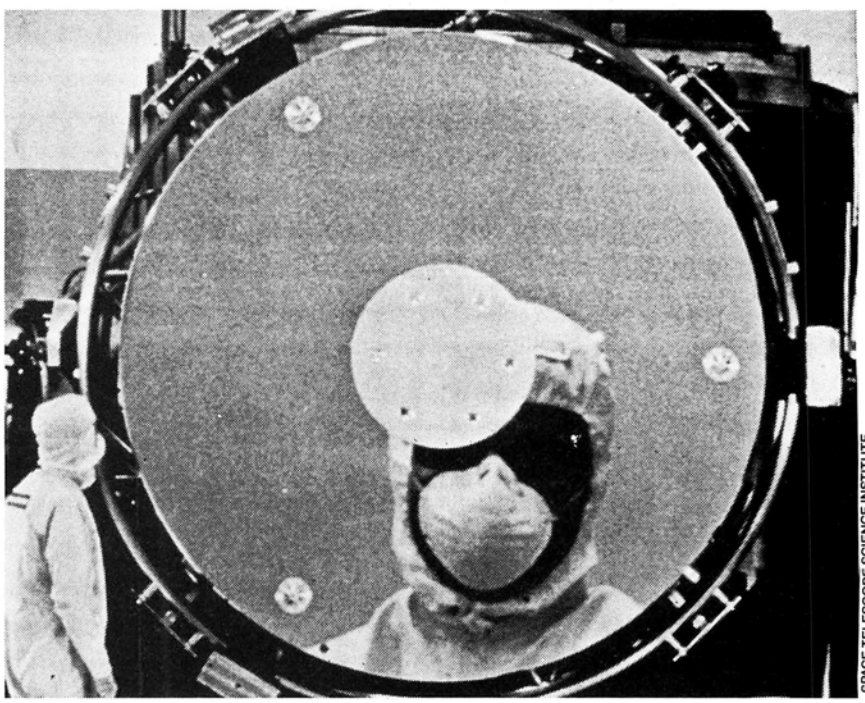
How do you get an ultra-delicate, 25,000-pound telescope from the California coast to its launch site on the other side of the continent? Back in 1986, when NASA's Hubble Space Telescope was originally scheduled for launch, that presented quite a problem. The 14-foot-diameter telescope was too large to travel by truck, and no aircraft could accommodate its special, environmentally controlled container. Even NASA's "Super Guppy" was too small. So shipping it through the Panama Canal on the Navy's giant USS Greenwave looked like the only option left.

But with the extra time bought by successive launch delays, NASA and Lockheed, the telescope's builder, have had a chance to rethink their plan. The Panama Canal, after all, is subject to violent hurricanes and political unrest. And even though the Greenwave could have been modified to carry the telescope, *because* of other commitments it could only have done so in May or November—forcing a long, risky wait at the Florida end of the trip, which itself would have taken two weeks.

Earlier this year, says Lockheed's program manager Jim Carlock, the Air Force came up with a solution: a newly modified C-5A cargo aircraft that can carry a shuttle bay–sized cargo. So come October, Hubble will roll into its container on wheels and rumble at a leisurely five miles per hour down a private road from Lockheed in Sunnyvale, California, to Moffett Field, about a mile away, where the big cargo plane will be waiting to transport the pride of the astronomical world to its Florida launch site.

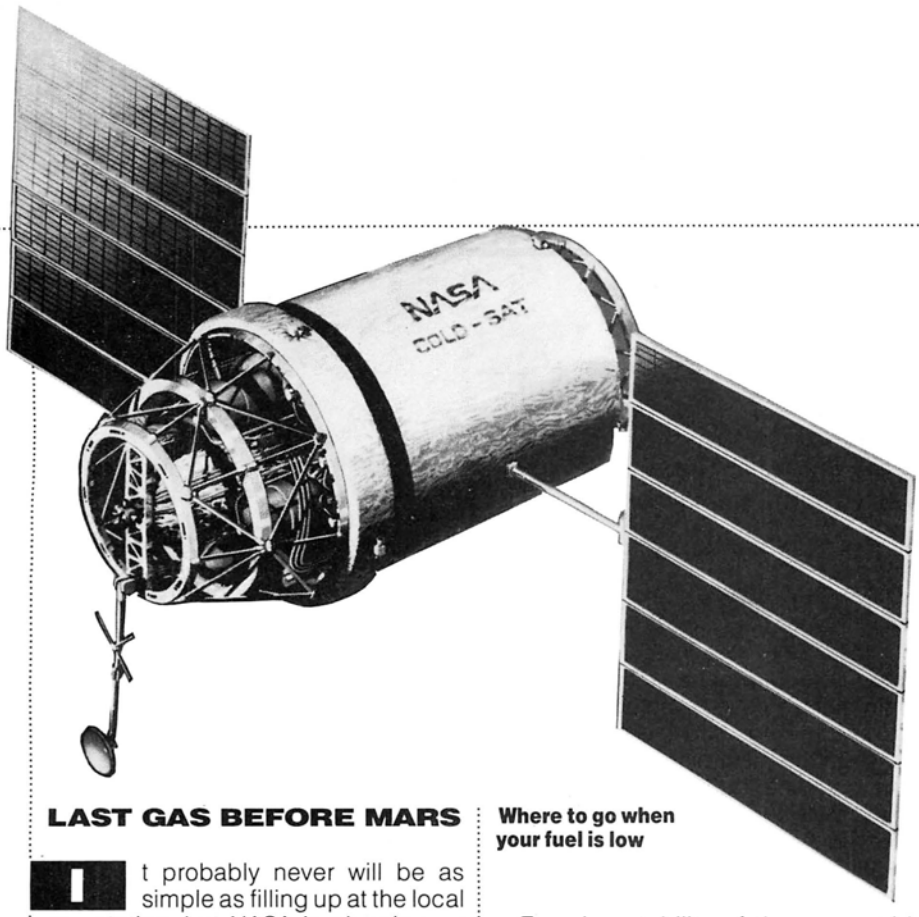
Maintained on the ground at a cost of $7–8 million a month (including upgrades) since 1986, the giant telescope is planned finally to reach orbit next March, when it will begin revealing the secrets of quasars, black holes and the size of the universe itself.

—*Ray Spangenburg/Diane Moser*



SPACE TELESCOPE SCIENCE INSTITUTE

A technician's face is reflected in Hubble's soon-to-be-orbiting main mirror.



LAST GAS BEFORE MARS

Where to go when your fuel is low

It probably never will be as simple as filling up at the local gas station, but NASA is planning an orbiting satellite that may serve as a refueling point for missions to the Moon or to the planets.

Scientists and engineers at Lewis Research Center in Cleveland are working with private companies and other NASA centers to refine designs for the Cryogenic On-orbit Liquid Depot–Storage, Acquisition and Transfer, mercifully known by the simple acronym "COLD-SAT." The ultimate goal is to park COLD-SAT in orbit, possibly at a libration point near the Moon, where inbound or outbound spacecraft could stop over and tank up with the supercold fluids.

COLD-SAT's refueling capability would be a big step forward in developing long-range missions to Mars and beyond. Another potential use for the satellite is the storage and transfer of hydrogen and oxygen mined from asteroids or from lunar rocks.

One major problem involves temperature control. With cryogenic fluids, vapors form easily, and in space it isn't practical to "just open a vent and let the gases escape," explains Patrick Symons, manager of cryogenic fluid technology at Lewis. Vapors can affect propellant transfers; as super-cooled fluids move into an empty tank, which generally is warmer, the formation of vapors could cause the tank to burst. In addition, those same vapors can distort sensor readings. "It's not like a gas gauge on your car," Symons says.

Ensuring stability of the supercold fuels also remains a priority, since the tanks may remain in storage for lengthy periods. After all, it may be a long time between fuel stops for future space travelers.

—Bob D. Gibson

PORTABLE POWER

When the commander of the Space Shuttle wants to shave, he plugs his razor into a fuel cell. Inside the cell, hydrogen and oxygen combine to form H_2O. The reaction produces a current, which powers the spacecraft's electrical system.

Now a Wyckoff, New Jersey, company called Ergenics Power Systems plans to bring some of that technology down to Earth. The firm has developed a small, portable fuel cell capable of running a 100-watt lamp for three hours. Designed to replace current rechargeable battery packs, the unit pulls oxygen from the air and carries hydrogen in a cartridge full of special metal alloy grains. The grains absorb the gas, storing it safely as a hydride.

"It's good for a number of applications where you need silent, portable power," says Ergenics vice-president Matthew Rosso. The company's prototype can be refilled from a pressurized hydrogen source in just 15 minutes, and operates well in sub- zero temperatures that hamper batteries.

Best of all, it weighs just 13 pounds, which already has caught the attention of many video cameramen, who now have to lug around 66 pounds of nickel-cadmium batteries to get the same amount of power.

Ergenics is looking for a business partner to help perfect the unit and put it into wide use. In the meantime, the New Jersey firm has its hands full designing a similar unit for NASA. Ergenics' contract with the space agency calls for the development of a compact, reusable hydrogen-oxygen fuel cell to power the life-support systems of astronauts during extravehicular activity. With hundreds of spacewalks planned for space station Freedom, NASA needs something to replace the short-lived zinc-silver oxide batteries now carried in astronauts' backpacks.

On Earth, fuel cell enthusiasts imagine a time when larger units will power everything from lighthouses to automobiles without polluting the air, warming the atmosphere or waking the neighbors. For now, pragmatists like Rosso believe that scaled-down versions can be used to fill small, specialized niches: computer back-up systems that provide emergency power for weeks instead of minutes, or environmental monitors in remote, frigid climates. If fuel cell technology is as promising as it seems, such limited uses could be the start of something big.

Shuttle shavers may be the start of something big.

—S. Matthew Sabatini

BACKYARD UNIVERSE

In Voyager's Footsteps

Take the "Grand Tour" with your telescope.

▼ ▼ ▼

By Blaine P. Friedlander, Jr.

Despite all its later triumphs, the first of two Voyager probes went virtually unnoticed when it was launched from Cape Canaveral on August 20, 1977, as America mourned a monarch. Elvis, the King, was dead.

Blockbuster news stories always seem to bump the Voyagers' triumphs to the inside pages of history. Back in 1979, the falling Skylab space station concerned people more than Voyager 2's fly-by of gaseous Jupiter. As the Voyagers made their passes at Saturn, Reaganomics dominated the headlines. And Voyager 2 gave us the first close-up look at Uranus just two days before the Challenger tragedy eclipsed every news story for months.

Finally, Voyager 2 has the stage to itself. Its twin, Voyager 1 (launched about two weeks *after* Voyager 2), has veered out of our Solar System for the hinterlands of the Milky Way, while Voyager 2 explores distant Neptune alone.

You may catch up with the Voyager spacecraft, tonight and any other night for the next few months, from a place as close as your backyard. It takes only a few minutes to tour the probe's last *three stops*; Saturn, Uranus and Neptune are close to each other in the constellation Sagittarius.

Sagittarius looks like a teapot hanging over the low southern sky. Saturn will be the only planet visible to the naked eye, hovering above the teapot handle. The constellation and its current planetary companions will be visible for the first half of the night.

Saturn's rings display their magnificence best when they're fully tilted as seen from Earth. With the power of a moderate telescope, mounted on a firm pier, you should be able to distinguish the rings *and* the shadow they cast on the giant planet. Look also for the dark line in the rings called Cassini's Division. The Voyager encounters proved that this large gap is caused by gravitational forces from Mimas, one of Saturn's 17 known moons.

The two planets visited only by Voyager 2 are much harder to find for those without skygazing experience. Let's be honest: These planets ain't too bright. Finding them on your own for the first time can be done, but it's not easy.

Astronomers judge "naked-eye" visibility to be about +6.0 magnitude (level of brightness). Uranus, right now, weighs in at about +5.6 magnitude. Hot, humid, summer nights don't help. Go to the darkest place you know, preferably far from the cities; a place that offers fresh air and clear views of the heavens. Distant hilltops or mountaintops will do nicely, as will unpopulated beaches that have little night light.

Uranus is a little blue dot to the right of Saturn. Don't be disappointed – even in binoculars and telescopes, it *still* looks like a little blue dot. Feel fortunate to see Uranus at all. It's 1.8 billion miles away, and it took Voyager 2 about eight and a half years to get there.

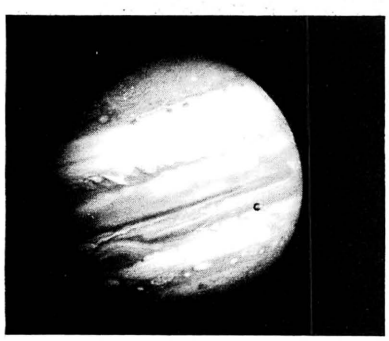
Well beyond Uranus lies Neptune, the target of Voyager 2's last close encounter. The spacecraft stretched its resources to get there, using Uranus' gravity to propel itself toward its goal. Even at 40,000 miles per hour, Voyager's trip from Uranus to Neptune took another three and a half years.

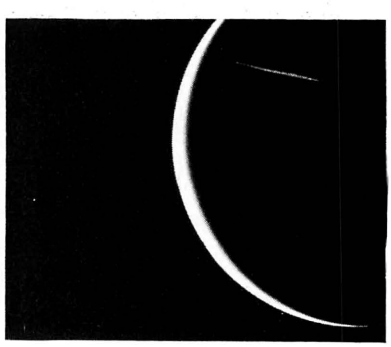
Through a moderately-powered telescope, Neptune is a bluish speck to Saturn's left. It's almost sitting on Saturn's shoulders. Neptune's faint +7.9 magnitude doesn't lend itself to hazy, summer viewing. But, considering how far the planet is from your backyard, the viewing is prime.

If you stay up past the late news, you'll find Jupiter, the first planet the Voyagers visited. A luminous object at -2.1 magnitude, Jupiter rises in the east late at night. One of the best objects to catch, the giant planet can be seen well with the naked eye, a pair of binoculars or with any size telescope. In a small telescope, Jupiter's four largest moons—Ganymede, Callisto, Europa and Io—dance around the king planet. You also may see some of the turbulent atmospheric bands (or "belts") that encircle Jupiter. In a moderate-sized 'scope, the Great Red Spot, a centuries-old cyclonic storm, comes into focus.

Even with an ordinary telescope, you can accomplish in a few hours what it took the Voyager probes years to do. You can explore for yourself the great milestones of the outer Solar System—or, in Voyager's case, *billion*-milestones. □

The story so far: Voyager's first three stops were Jupiter, Saturn and Uranus.





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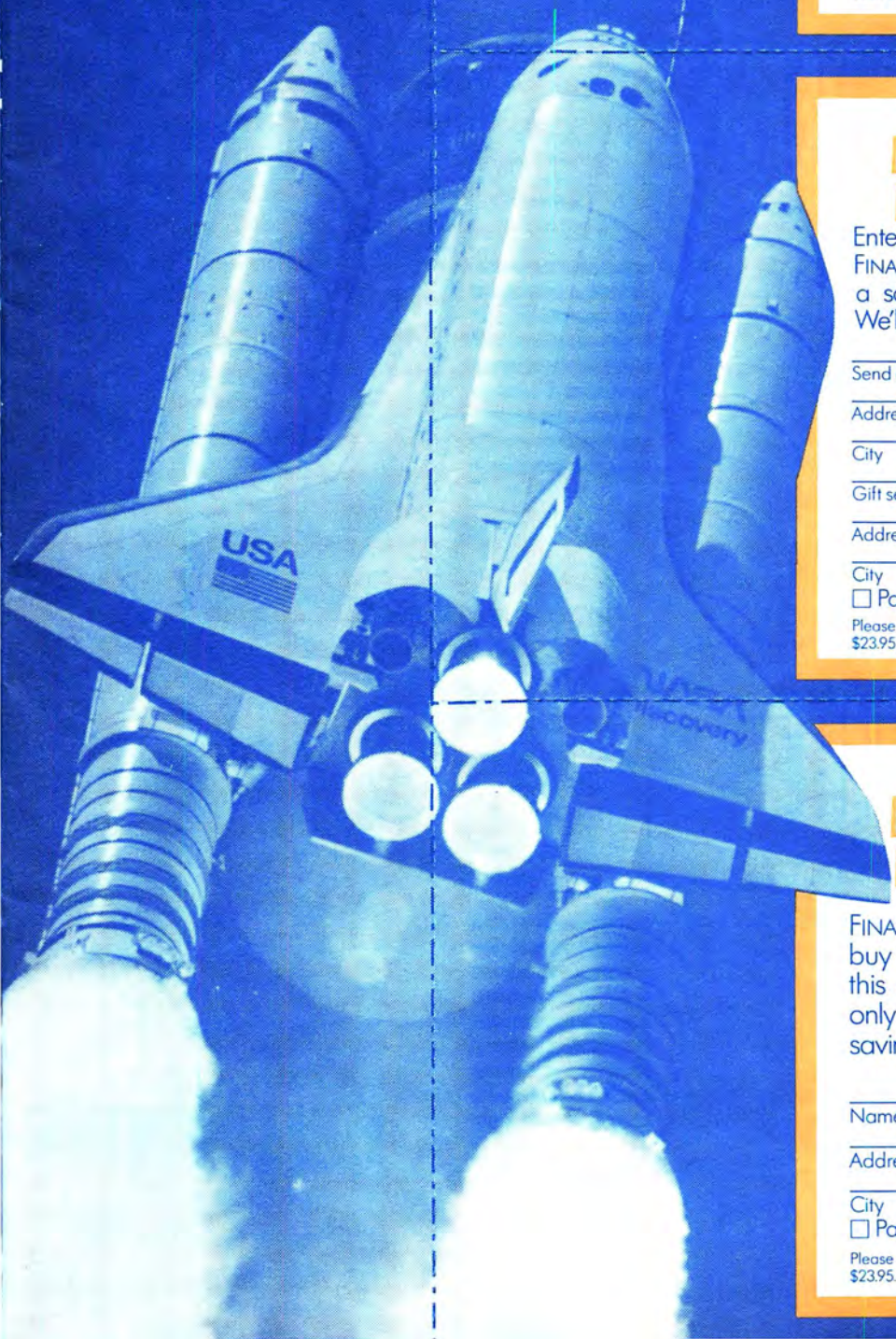

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- No batteries—it's rechargeable!
- Perfect for international (and interplanetary) players—it's not language specific.
- Selected by Innovations '88 Design and Engineering Exhibition at the International Consumer Electronics Show in Chicago, Illinois as "One of the most innovative consumer products of 1988."
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How to Beat the High Cost of Space

Technological "magic bullets" are one answer. But NASA, Congress and the aerospace industry also need to take a hard look at the way they do business.

BY GARY STEPHENSON AND GREG FREIHERR

Standing like a silver needle on the launch pad at Cape Canaveral in December 1957, the Vanguard rocket was more a monument to American politics than to engineering. It had been an esoteric project with little political significance until the embarrassment of the first two Sputniks. Vanguard's response to the Soviets was a spectacular failure on the launch pad, as the rocket crumpled into a ball of flames.

President Eisenhower tried to explain: "Vanguard...has not had equal priority with that accorded our ballistic missile work....Our satellite program has never been conducted as a race with other nations."

That soon changed. Within weeks an American satellite was fired into space atop a military booster, and an all-out competition with the Soviets was underway. The race finally ended in 1975, with the detente of Apollo-Soyuz. But even before that symbolic handshake in orbit, the political force that had driven the early space program had almost completely disappeared.

Today NASA, which took shape at the height of the cold war, is struggling for direction. It seems there's not enough money to do everything. Despite sizeable increases in the space agency's budget, to more than $10 billion last year, NASA talks like a pauper.

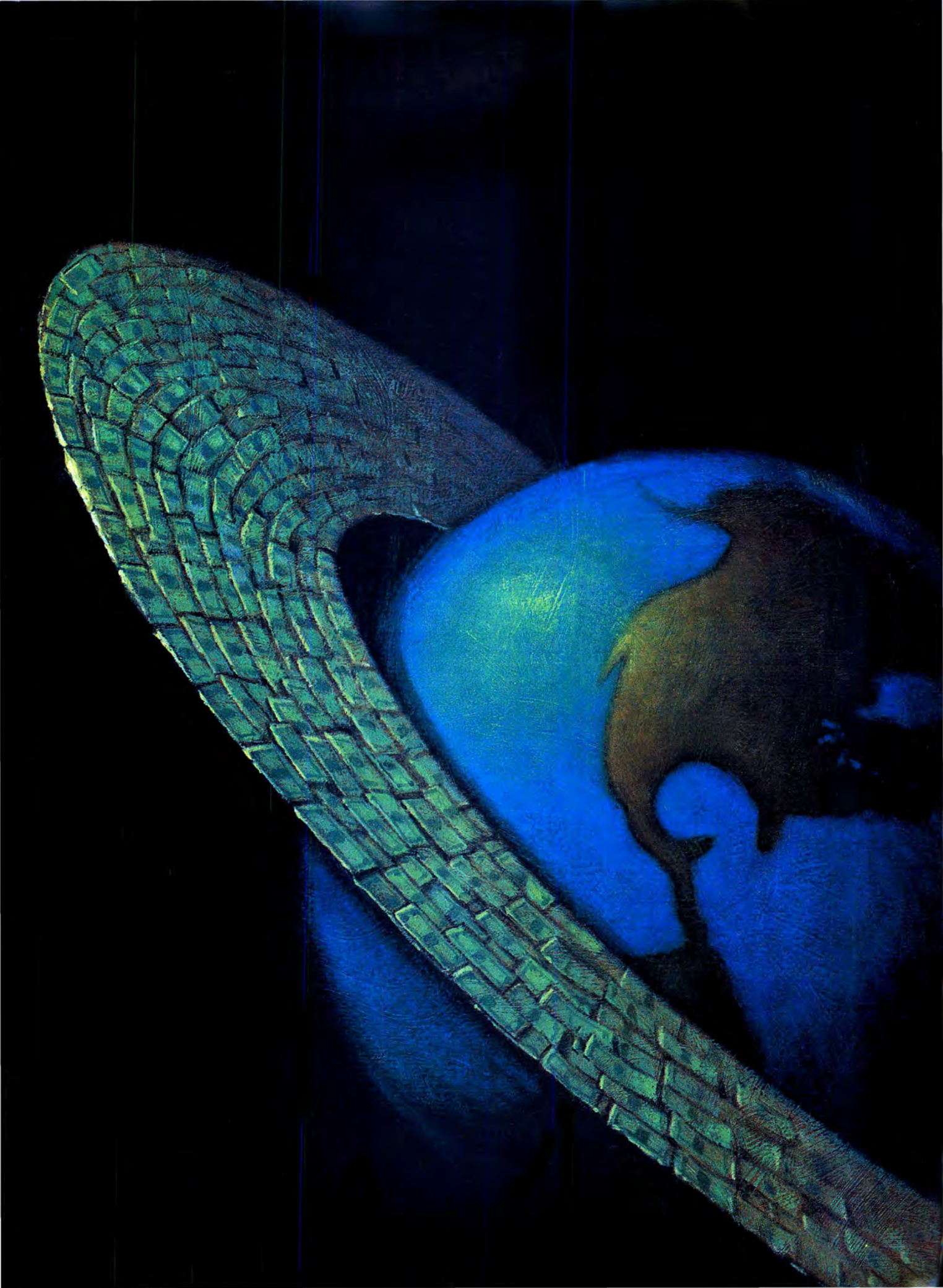
Is it time for America to choose which field of space exploration it will lead? Choose between astronauts and robots? Let other nations pick up the slack? If it does, the United States will have made the easy choice. The hard ones—those that might improve the way the nation conducts its space business— will have gone untried.

The problems are rooted deep in America's history, yet they are as new as the next moment. It is that duality that is so vexing. What has made America strong is now threatening to make her weak.

Since the industrial revolution Americans have been in love with technology—new, expensive, untested technology. The overwhelming need to have the newest and the best borders on an addiction. And it has to stop.

"We may be on the verge of technology saturation, and that's why we need to manage and innovate based on current technology," says Kenneth A. Kovaly, president of Technical Insights, Inc., which specializes in tracking the development of technology worldwide. "There is just too much technology out

STEVE JOHNSON



How to Beat th

Borrowing from the past to meet present needs: The Magellan (top) and Pegasus projects both lowered their development costs by improving and adapting existing technology.

there, waiting for new development to make it useful."

Slowly, space engineers are beginning to pull existing technology off the shelf, modify it and turn it into something new and cost-effective. NASA planetary scientists, perpetually starved for money, cannibalized old Voyager, Mariner and Galileo spare parts for the Magellan Venus probe—a cheaper solution than designing and building a new spacecraft from scratch.

In some cases, private industry has been the catalyst. Pegasus, a new booster launched from the wing of an airborne B-52 bomber or commercial jet, is basically an improvement on technology developed for the X-15 project in the 1960s. Orbital costs are still high—about 60 percent more per pound than with larger boosters such as the Delta 2. But Pegasus promises quick access to space for small payloads, which may help to create a new market for affordable space experiments.

This "adapt and improve" philosophy also extends to computer technology. During the late 1970s, the non-space research community saw a boom in the use of automation, artificial intelligence and advanced electronics. Until recently, space engineers had yet to take advantage of some of those advances. But NASA and the Defense Department recently demonstrated a computer that combines existing hardware and software, which can rival supercomputers in solving highly defined problems, yet is within the price range of individual laboratories. The development is not earth-shaking—scientists in other fields have been hooking up less powerful computers for years. Even the concept of parallel processing to solve several parts of a problem simultaneously, rather than sequentially, is old. And that is its beauty.

But existing technology isn't always up to the job. NASA has long recognized that one way to bring down the cost of spaceflight is to improve performance through automation, and the biggest long-term gains are promised by the most advanced systems.

The development costs for a system to control electrical power generators on space station Freedom, for example, will be about $85 million if "expert" computer systems are *included*; $75 million if off-the-shelf automation techniques are *applied*; and $45 million if an astronaut-controlled system is used. Cost savings could be realized in as little as two to four years if the automated systems are chosen. After that, annual operations would run about $30 million for the manual system; about $13 million for conventional automation and $10 million for expert systems. But higher upfront expenses are hard to swallow politically.

What's needed is a judicious mixture of old and new technology. Borrowing from past research to meet present needs may be the solution in one case. Investing in new technology to build a foundation for the future may be appro-

ALS: The Dream Machine

"Big is not necessarily complex." Col. John Wormington pauses to let that last statement sink in. I can tell, even over the phone, that the walls of his office at the Air Force Space Division in Los Angeles must be covered with such slogans.

"We don't have a national launch capability that we can trust," claims the man in charge of the Air Force/NASA Advanced Launch System (ALS) program. And his single-minded mission is to see that we build one.

If he succeeds, Wormington will realize the dream of many a space visionary before him: finding a cheap, reliable means of getting to Earth orbit. The first hundred miles of any space voyage are still by far the most expensive. And without a low-cost alternative to today's launchers, our dreams of going to the Moon, Mars and beyond may never happen.

So Wormington is working on solutions. "Amateurs talk strategy," he says, quoting a Prussian army dictum. "Professionals talk logistics."

e High Cost of Space

priate in another.

Through its Pathfinder program, NASA has started looking at innovative propulsion systems, robotics, even methods for extracting minerals from the planets, Moon and asteroids. Pushing the technology in these selected areas promises cost savings in future NASA operations. For example, aerobraking, which reduces the need for retro-rockets by using atmospheric drag to slow a spacecraft arriving in orbit, would cut down on the weight and expense of a Mars mission. An aerobraking demonstration flight in Earth orbit is now scheduled for 1994 on the shuttle.

But there is danger in pursuing new research within a bureaucracy. Even when it's justified, innovation has to be planned. New technologies have to fit in with existing ones, or they will not—in fact, cannot—be applied.

Case in point: At the Kennedy Space Center in Florida, V. Leon Davis, chief of the robotics section, is trying to build a robot that will automatically connect and disconnect fuel line umbilicals to the space shuttle. What takes a launch crew up to 30 hours to connect could be done by a computer-driven robot in *three minutes*, he says. Fuel lines would be mounted at the end of a robot arm and jammed into connectors on the shuttle, held in place purely by the force exerted by the robot. It would eliminate the need to connect, and then tighten, individual valves.

The KSC team has made significant progress, proving the potential of its invention in laboratory tests. But Davis acknowledges that the robot, if ever built, probably will not be used on the current space shuttle.

"Methods don't generally get changed just because something is better," Davis says. Rather, the technology has to be part of the overall design scheme of the vehicles it will service. The fueling robot may have to wait for the proposed Shuttle C, an unpiloted version of the shuttle now being considered by NASA as a possible heavy-

GENERAL DYNAMICS

"A truck, not a race car."

Program managers for the ALS use the Air Force's Titan 4 — which prices out at $3600 per pound to orbit — as their yardstick of current launch costs. By simply taking a new design approach and applying new (but not revolutionary) technology, Wormington says, ALS can get the number down to about $1000 a pound at today's launch rates.

In order to achieve the economy of scale that would lower the cost to $300 a pound, however — the factor of ten reduction that is ALS' stated goal — he figures the nation would have to be launching 20 to 25 vehicles a year, with 150,000 pounds of cargo each — a level of activity associated with a lunar base, a Mars expedition or the Strategic Defense Initiative.

A key to the ALS design approach is simplicity. "We're building a truck," says Wormington, "not a race car." And that means sacrificing performance for the sake of durability. The main engine for the ALS will have far fewer working parts to break down than does the high-performance space shuttle main engine. The ALS engine may be heavier and less efficient — its turbopumps will produce only 35 horsepower per pound of weight, as compared to 100 horsepower for the space shuttle — but it will cost much less to produce and to pamper.

The losses and delays that plague delicate, high-technology launch operations have to be factored into the overall cost equation, says Wormington. For that reason, ALS probably will carry more redundant backup systems even than the manned, safety-conscious space shuttle. Although it will pay a weight penalty by lugging along backup engines and extra instruments to monitor its own health, the ALS will make up for it in terms of operational reliability. In fact, says Wormington, the unmanned vehicle should prove so safe and reliable that, eventually, "astronauts will beat a path to our door to fly on it."

Another ALS goal is to streamline the manufacturing process. "The primary cost of anything we do is the people," says Wormington. A pound of aluminum, for example, costs only two dollars. But by the time highly trained technicians cut, shape and fashion it into a panel installed on a Titan rocket, the price has risen to $90 a pound. So the ALS program will again stress cost savings over race-car performance. Instead of milling each piece of metal to very precise, delicate tolerances, heavier and lower-tech parts could be mass-produced by machine.

Wormington also has schemes to cut down on the large army of workers now required to launch a rocket into space. ALS vehicles will be assembled, tested, fueled and launched at the same facility, often by the same people. Titans, by contrast, are built and tested in Colorado, then taken apart

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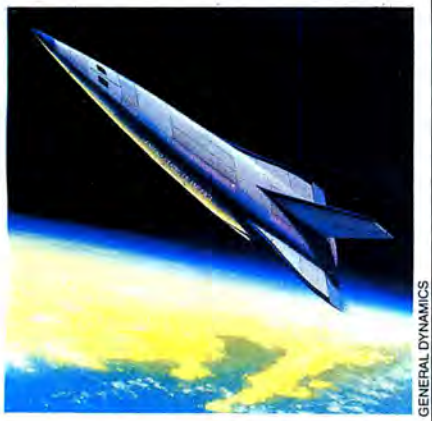
How to Beat th



GENERAL DYNAMICS

If space station Freedom and the National Aerospace Plane are to advance new technology, the costs will be high, and politicians will need to follow through on their commitment.

lift vehicle. On Shuttle C, Davis says, the robot "could result in major structural improvements. We're talking about tremendous savings in the operation of that vehicle."

Support operations account for a huge amount of the expenditures needed to explore space. Keeping an astronaut in orbit costs between $10,000 to $100,000 per hour, depending on the size of the shuttle crew and what they are doing. Ground personnel alone—including launch pad crews, mission controllers and support teams at the landing site—eat up a large share of the cost of each shuttle mission.

NASA is making some headway in reducing this expense. The launch of the last Tracking and Data Relay Satellite into orbit, for example, allowed the agency to save money by closing several tracking stations on Earth.

The Office of Technology Assessment (OTA), which advises Congress, has come up with a number of suggestions for streamlining space operations, including the greater use of built-in test equipment for space hardware; automated inspection procedures; "fault-tolerant" computers; automated handling of launch vehicles and payloads; computer-aided software development and expert computer systems.

When it comes to automation, says OTA's Ray Williamson, "It is my impression that NASA has not done all it can. They have computers all over the place, but when it actually comes to scheduling parts of the launch process, that all goes on paper." Changes require at least five engineers to sign off. "The same piece of paper is passed on, and it sits in someone's in-box," Williamson says. "It takes forever."

This and other inefficiencies are reflected in the high cost of launching payloads into orbit—$3,800 per pound on the Delta 2 booster; between $3,100 and $4,100 on the Air Force's Titan 4; and between $3,000 and $3,500 on the space shuttle.

The shuttle's reusability has kept its costs down despite the extra expense associated with flying astronauts. But the number NASA cites for the shuttle is based on 14 flights per year. This year it will make no more than six flights, if that.

The great promise of the National Aerospace Plane project is that it will lead to space vehicles that are more like commercial airliners, with the sheer volume of traffic bringing costs down. But those savings, if achieved, may be decades away. Near-term costs might be reduced to about $2,000 per pound with NASA's Shuttle C, and as little as $300 per pound with the Advanced Launch System (ALS), a joint Air Force/NASA endeavor (see page 20).

Hopes of success for the ALS are based partly on such innovative approaches as replacing hydraulic systems with electro-mechanical devices. This alone has the potential to reduce ground processing time by 9,000 hours.

But whether ALS will succeed is debatable. Despite its stated goal to bring down launch costs by a factor of ten, Air Force officials have already begun saying that it may only be possible to cut costs to $600 or $1,000 a pound.

The realization that these reductions may not be achieved is old hat to veterans of the space industry. Lowering the cost of spaceflight was, after all, one of the primary reasons the space shuttle came into being. "Although they all have good intentions, this cadre of people [working on ALS] still come from an aerospace community used to doing business the old way," Williamson says.

The underlying problems that plague this country's space efforts are deeply rooted in a bureaucratic and political system that usually seeks cures to its ills in technological "magic bullets." Instead of addressing the fundamental way it does business, the system pins its hopes on the next new machine, whether it's the space shuttle or the aerospace plane. Then, all too often, the system's inherent problems creep back in.

Multi-year, multi-billion dollar contracts to build these new machines are awarded to aerospace companies on the basis of paper promises—proposals wrapped around unproven expectations. In essence, contractors

e High Cost of Space

do not sell products; they sell promises to make products.

The much talked about "privatization" of NASA that supposedly would save money by involving private industry in space activities has already taken place—and it has failed. In farming work out to contractors, the government does not achieve the lean efficiency of competitive industry. Generally, it's the other way around—industry adopts the inefficiencies of government.

When it issues a "Request for Proposals" (RFP) for a particular project or piece of space hardware, a government agency like NASA tells the contracting world what the product should look like, how much time it should take to build, even how many "person-hours" should be spent. A contractor who proposes anything outside those parameters, or who comes up with a truly revolutionary approach, risks having its proposal rejected.

Some RFPs even tell contractors that if they venture outside the bounds of the government request, they must prove that their idea is better or be found "nonresponsive." That alone is grounds for rejection—and reason enough to take the easier course of giving the government what it wants.

Not surprisingly, when NASA asked industry for preliminary designs for its permanent orbiting space station in 1984, every contractor came back with the "dual keel" design favored by the space agency. That configuration was later dropped. Too expensive, NASA decided.

Extending the level of competition beyond the proposal stage might be one answer to the problem, but government agencies have little interest in such a solution. Just getting through the *existing* procurement procedure taxes the stamina of agencies and contractors alike. Sometimes red tape and procedural requirements dominate the entire process. In late May, NASA short-circuited its own bid process for selecting a contractor to build the Advanced Solid Rocket Motor, an upgraded version of the solid boosters now used by the shuttle. Some of the pages in the "best and final" offer prepared by the team of Lockheed and Aerojet turned up missing. The agency decided, rather than put Lockheed/Aerojet at a disadvantage, to award the contract on the basis of the proposals that were submitted initially. Lockheed/Aerojet won.

To say that competition is hamstrung by the awards process is an understatement. Contracts in the hundreds of millions of dollars often require a "Phase B" competition—a face-off between two contractors for six, nine or

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Compared to What?

No question about it, space exploration costs a lot of money. But these days, how much is a lot? With the help of a few handy references, including the *Harper's Index* and the *Information Please Almanac*, we checked the price tags on some other high-budget items that our society deems worth the expense.

For example, this year's budget request for space station Freedom is $2.1 billion. That's roughly one-fourth the amount Americans spend each year on pornography, and half what they spend on perfume.

The cost of the entire Voyager program, from launch in 1977 through Voyager 2's rendezvous with Neptune in 1989, comes to $556 million. That's just six million more than junk bond trader Michael Milken "earned" as personal income in 1987. It's about $50 million more than Americans paid for products related to Halley's Comet during its last visit. By comparison, moviegoers shelled out a combined total of $503 million through the end of 1987 to see *Star Wars, Return of the Jedi* and *The Empire Strikes Back*. Meanwhile, a single "Stealth" bomber goes for $531 million, and the current plan is to build 132 of them.

One space shuttle flight—if you divide NASA's 1989 budget for shuttle operations by the number of missions flown this fiscal year—costs $400 million. That's about the same amount Coca-Cola spends each year on advertising. Speaking of which, direct mail advertisers spent a total of $19.1 billion in 1987 to clutter your mailbox—roughly twice the amount NASA spent in that same year.

What's the *real* cost of the Search for Extraterrestrial Intelligence? NASA's ten-year program to listen for alien radio signals is priced at around $80 million—an average of eight million a year. Compare that to the Pentagon's 1986 phone bill ($84.8 million) or to the amount spent by the University of Alabama on athletics during one (1985-86) season ($8.6 million).

And next time someone tells you we can't afford the space program, be sure to ask who *we* are. According to *Forbes* magazine, the combined net worth of the 400 richest Americans is a whopping $156 *trillion*. Even if all 400 flew to Mars in the same spacecraft (a stretch model with built-in bar, no doubt), there'd probably still be enough money left over to fill the supply ship with caviar. □

—Tony Reichhardt

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FINAL FRONTIER'S

DARING DOZEN

In this issue of *Final Frontier* we salute the "Daring Dozen," those captains of the starship enterprise who are taking chances, staking claims, shaking, moving and otherwise working to make commercial space activity a reality. ■ They include an astronaut, a scientist, a starry-eyed inventor, an insurance underwriter and even a Soviet bureaucrat, all of them struggling against long odds to make space enterprise a powerful new force in the world economy. Risk-taking is the common thread in their stories, and not just because space is risky business. The sheer determination of the Daring Dozen in the face of reluctant governments and financial markets makes them true pioneers of the final frontier. ■ As this issue was going to press, we received the tragic news that one of the twelve–George Koopman of AMROC–was killed in an auto accident July 19, while driving to yet another test firing of his rocket in the California desert. Our profile of Koopman remains as originally written, in testimony to the entrepreneur who epitomized the spirit of the Daring Dozen. May the rocket man's dreams survive him.

BY MELINDA GIPSON

THE DARING DOZEN

PAM FRANCIS

Allen: "We stand behind what we say we can do."

JOE ALLEN

The Astronaut

Until Joe Allen got into the space business, he never knew what it felt like to fail. A Fulbright Scholar with masters and doctoral degrees from Yale, an astronaut for nearly two decades, Allen had reached the top of every field he ever entered.

He flew on the first operational shuttle flight in 1982, and is probably best remembered for the 1984 mission that retrieved two orbiting satellites and returned them to Earth—that's Allen in the famous "For Sale" photo, posing with one of the recovered satellites in Discovery's cargo bay.

But what was to be an even more meaningful encounter took place in 1967, on Allen's first day in the astronaut corps, when he met Max Faget, the legendary designer of the Mercury spacecraft.

Allen remembers, "Max said in 1975 the shuttle would need an outpost to go to—some kind of man-tended platform that could grow into a permanently manned station." In 1982, Faget founded Space Industries Inc. to design and build such an orbiting outpost, which became known as the Industrial Space Facility. He asked Allen to join him. In 1985, when the astronaut quit flying for NASA, he agreed.

Allen took the job as Space Industries' president partly because of Faget's genius, and partly, he says, because, "If we didn't find some way to keep the costs down, the space industry was going to price itself right out of the market."

But four years after Allen came onboard, a market has yet to develop for Space Industries' mini-laboratory. A plan to have NASA sign on as a guaranteed customer ended in failure last May. When such a "Commercially Developed Space Facility," or CDSF, is viable, said the space agency, the decision should be made by the marketplace, not the government. Space Industries had gotten no help from two reports—by the National Research Council and the National Academy of Public Administration (NAPA)—concluding that the idea of a privately funded microgravity lab was ahead of its time.

Allen contends that NAPA's $3 billion estimate for building and operating a commercial facility is too high. Not only would Space Industries' ISF be useful before space station Freedom is available, it could be "designed, developed, manufactured, tested and operated for comfortably under a billion dollars," Allen says. The only reason NAPA didn't come to that same conclusion is that it was working with NASA's specifications, not the ISF design.

But Allen and Space Industries have

no intention of disappearing quietly. While they wait for ISF's number to come up, they've begun exploring other commercial services. With the support of a $5.6 million NASA grant, the University of Houston has contracted the company to build a "wake shield"—a kind of umbrella dragged behind the shuttle that provides a super-clean atmospheric environment for experimenters working with thin films used in opto-electronic research.

NASA had tried to design a wake shield with McDonnell Douglas as its feasibility study contractor, but found the project was getting too expensive—nearly six times Space Industries' current estimate. Allen hopes to make the product available commercially.

The shield will be built by the newly acquired Precision Aerospace Manufacturing Company, which is run by an ex-senior machinist at Johnson Space Center. That isn't Space Industries' only recent acquisition. On its way toward becoming a full-service space company, it bought Payload Systems, Inc., best known for negotiating a deal to orbit experiments on the Soviet Mir space station (see page 34). Also in the works is a joint venture with Los Alamos National Laboratories on ways to process electronic materials and alloys in microgravity.

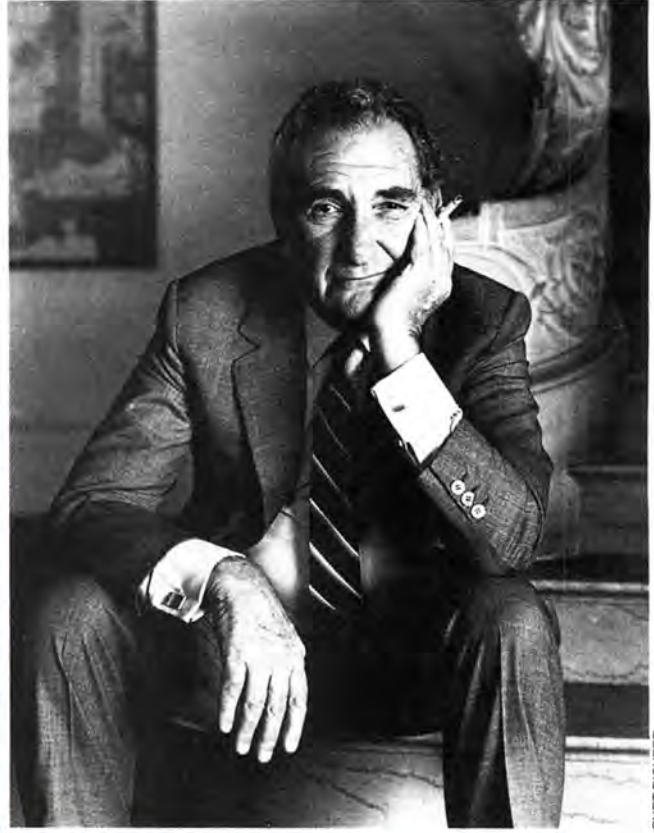
"We're providing end-to-end services with the industrial approach—meaning that we build what's necessary, inexpensively," says Joe Allen. "We're not an airbrush company. We stand behind what we say we can do."

RENE ANSELMO

The Humorist

There's nothing particularly funny about risking $85 million of your own money in a head-to-head competition with a heretofore unassailable international cartel. But Rene Anselmo is laughing anyway.

The chairman of Pan American Satellite is a very serious businessman with an unflagging, barbed wit, which he uses to skewer any of the satellite industry's high and mighty who have the bad taste to get in his way. Last year, Anselmo's company launched the first satellite in a $200 million system that will provide communications services to the United States, Latin America and the Atlantic Basin.



CURT RICHTER

Anselmo: Serious businessman with a barbed wit

It had been the almost single-minded crusade of Richard Colino, former director general of the Intelsat organization, to strangle the very notion of a competing international satellite system in its cradle. But Anselmo, a Hispanic broadcaster with strong ties to Latin America, knew that all was not roses in Intelsat's garden. In order to serve the entire world economically, Intelsat's satellites have to cover large areas with wide beams. This means that ground equipment has to be large and expensive, which poses a problem for developing countries in Latin America.

Although there seemed to be a logical opening in the market for higher-powered satellites, Anselmo knew better than most satellite executives that the business he chose isn't always ruled by logic. When he filed with the Federal Communications Commission in May 1984 to launch his international service, there wasn't even a U.S. policy addressing whether it was possible. But by November of that year, President Reagan ruled that it was in the interest of the United States to foster such competitive international systems.

Though Anselmo won't swear that it was a factor, the edict came after a personal appeal to Reagan in one of the many notorious letters written in col-

laboration with his fictional dog, "Spot." Among Anselmo's (and Spot's) gripes to Reagan was that Independence Day that year was to be celebrated on a Wednesday, which mucked up everyone's weekend.

Other "Spot" letters distributed to the satellite industry during that period characterized Intelsat contractors Ford Aerospace and Hughes Aircraft as "Henry" (as in founder Henry Ford) and "Howard" (for Howard Hughes)—a couple of mobsters intent on foiling Anselmo's plans.

If some people found Spot's epistles amusing, Intelsat's Colino wasn't among them, and he continued to wage war tirelessly against PanAmSat's success. He might have succeeded, too, if he hadn't been convicted of embezzling a few million from his former employer. Colino is now serving time for the offense.

Still, the regulatory delays nearly cost Anselmo dearly. The launch of PanAmSat 1 on the first flight of an Ariane 4 launch vehicle in June 1988 was a photo finish. Because it was a promotional flight, Anselmo had paid a fraction of what any other launch vehicle would have cost. But Intelsat's deliberations on whether to coordinate the company's service with its own dragged on long enough to threaten the launch date. Fortunately, the Ariane vehicle ran behind schedule, and Anselmo met his appointment.

Even the suggestion that he has the stars on his side, though, provokes a gag from the industry humorist. Whenever Anselmo finds himself getting a big head about his success, he says Spot brings him back down to Earth by leaving a warm, wet spot on his leg.

JAMES BEGGS

The Comeback Kid

Jim Beggs, former NASA chief and card-carrying member of the "old boy" network, doesn't look or sound like a controversial character, much less a wildcatter in the space business.

But wherever he's gone he's made waves. As NASA administrator in the early 1980s, he left a legacy of success, and, admittedly, failure. No shuttle ever failed on his watch, though it did fail to achieve the airline-like operations promised by his predecessor—and later successor—James Fletcher.

SPACEHAB

Beggs: Card-carrying member of the "old boy" network

It was Beggs who first claimed he could build a space station "by the yard" for the absurdly optimistic price of $8 billion. (NASA's latest estimate, which many think is still too low, is $16.7 billion.)

Perhaps Beggs could have done it if he had stayed on at NASA. But in November 1985 he was indicted by the Justice Department for alleged fraud while a vice-president at General Dynamics, and was forced to resign. A few weeks later, he watched the tragically short flight of Challenger at home—or would have, if he hadn't earlier seen icicles on the launch pad and switched the television off, telling his wife, "They're going to scrub today, Mary. It's far too cold."

Beggs fought the fraud charges, and the Justice Department dropped its case after 18 months, acknowledging that it couldn't win in court. Vindicated, Beggs received an unprecedented, if politically motivated, apology from then Attorney General Edwin Meese.

Now, as chairman of Spacehab—a company struggling to sell a "mid-deck extension facility" that provides extra work space for shuttle experimenters—Beggs has made a comeback at an age when most people retire.

Even while Space Industries was trying to secure a long-term government lease of its Industrial Space Facility, Beggs was telling legislators that Spacehab didn't need one—the company could survive with only the support of industry and private investors. At first that meant only U.S. industry, but Beggs soon had the sense to look abroad for the nearly $100 million in funding that Spacehab needs to fly. Under his leadership, the company engaged Bear Stearns and Citibank as advisors in raising capital, and Beggs took the Spacehab concept on the road, netting strong expressions of interest from Japan, Taiwan and Singapore.

MICHAEL FREEMAN

Bond: Fighting the inertia of British officialdom

Because Spacehab has the kind of fly-now, pay-later deal that NASA offers only to U.S. firms, the company has to limit foreign equity investment to 30 percent. But an even greater amount may be structured as debt, putting the project in the vanguard of international space ventures.

Spacehab's success depends on whether the financial markets can be convinced to invest $100 million in a system that relies on a NASA agreement—a legitimate worry, considering how often the government has changed its mind in the past. In June, Chemical Bank agreed to underwrite a substantial portion of the debt, but with two large strings attached. First, Spacehab must find insurance for its module by the fourth quarter of this year, and second, it has to show that a market exists for renting out 50 experiment lockers per flight, at $1.45 million each.

In part, the company is counting on Beggs' connections on Capitol Hill and with his former agency to help guarantee the kind of government commitment that would satisfy the investors. But Spacehab also will rely on its international partners to drum up customers willing to pay for additional room on the shuttle. The company already has marketing agreements with 3M in the United States, with Aeritalia and Intospace in Europe, and with Mitsubishi in Japan. That gives three continents a stake in Spacehab's success—and Jim Beggs yet another opportunity to test his mettle.

ALAN BOND

The Inventor

Alan Bond was just 16 when he had his first run-in with the inertia of British officialdom. He had built himself a rocket, with which he intended to challenge the official world altitude record. But the local authorities in Derbyshire prohibited him from launching it.

Thirty years later, Bond built an engine for Rolls-Royce that he hoped would carry Britain into the 21st century at hypersonic speed. His classified design was called "Swallow"—so named because the engine was designed to swallow air and convert it to fuel that could take a spaceplane most of the way to orbit (rockets would do the rest). The spaceplane, called HOTOL for Horizontal Take Off and Landing, promised airline-like operations at costs one-fifth those of existing means of space transportation.

In 1988, Rolls-Royce exercised an option to buy the Swallow patent from Bond. Then, only four months later, the British government ignored appeals by a consortium of U.K. space companies and cut off further funding for the project. Kenneth Clarke, minister for space at the U.K.'s Department of Trade and Industry, said at the time that "the scale of funding required to develop HOTOL or any similar concept to eventual pro-

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THE DARING DOZEN

CHARLES BUGG

The Scientist

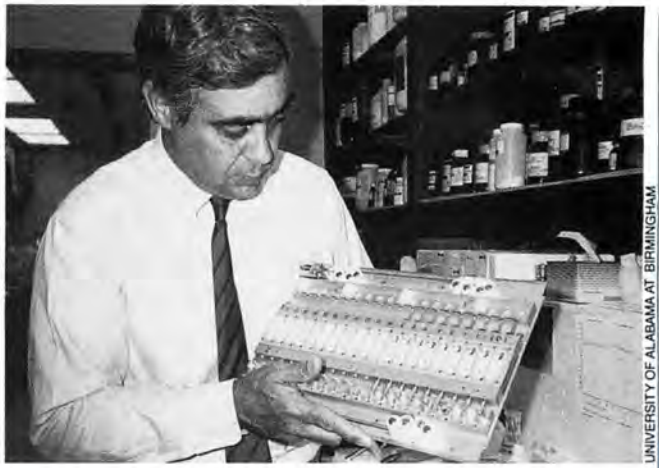
Thanks to Charlie Bugg, there's now a company in Huntsville, Alabama, that wants to find a cure for AIDS in space.

Bugg is director of the Center for Macromolecular Crystallography at the University of Alabama at Birmingham, one of 16 NASA-sponsored Centers for the Commercial Development of Space located around the country. Together with his "industrial affiliates"—pharmaceutical companies such as Eli Lilly, Upjohn, Merck and Schering-Plough—Bugg has pioneered research into how microgravity can be used to grow protein crystals that will help unlock the secrets of the human body and help treat disease.

Crystals don't give up their secrets easily. To understand the effects of certain proteins or enzymes, a scientist must first know how the crystal's molecules are ordered. The larger the crystal, the easier it is to determine its structure using X-ray diffraction and computer modeling techniques. And crystals grow to extraordinary sizes in space.

Bugg's center sponsored experiments on two shuttle flights in the last year alone, and expects to fly again in November. The crystals flown to date are already being used to study a wide range of diseases. Large, symmetrical, space-grown crystals of elastase, for example, will support Merck's research into drugs that could treat diseases like emphysema. DuPont grew isocitrate crystals in space, which have applications in developing fungicides. Upjohn grew phospholipase, useful in studying how to prevent human membrane tissue from deteriorating, and renin, which could help treat high blood pressure.

Burroughs Wellcome's study of reverse transcriptase crystals could help researchers to duplicate and better understand the AIDS virus. The Burroughs tests did less well than anticipated on both shuttle flights, because not enough time was available for proper crystal formation. But most of the experiments have been astonishingly successful; just how successful will be the subject of soon-to-be-published analyses by Bugg.



UNIVERSITY OF ALABAMA AT BIRMINGHAM

Bugg: Pioneering the frontiers of research

According to John Spitznagel, president of BioCryst, it was Bugg who first appreciated the potential commercial significance of a substance called purine nucleoside phosphorylase, or PNP. In the body, PNP can attack anticancer agents, making them less effective. If PNP can be neutralized, cancer drugs might be made more effective.

Not only did Bugg appreciate the importance of space-grown PNP, he found the funding to establish a new company to study it. With the help of Bill Spenser, a Birmingham businessman, Bugg raised $4 million for BioCryst's initial capitalization. The company already has established a collaboration with Ciba-Geigy, a Swiss pharmaceutical conglomerate. Together they hope to develop an inhibitor to PNP that could aid in treating cancer, AIDS, rheumatoid arthritis and other diseases related to the immune system.

As a result of its recent shuttle experiments, BioCryst filed for patents on six compounds and is preparing to file for eight to ten more. There are a lot of "ifs" in BioCryst's future, but it intends to be much more than "just a little research boutique," Spitznagel says.

"We see this research as a significant opportunity. If any of our compounds produce successful drugs, we think we are looking at a $50 million

company in the next five years."

Apart from Bugg and Spitznagel, probably no one is more interested in the success of the company than James Rose, head of NASA's Office of Commercial Programs. He looks to BioCryst as only the first of what he expects will become many companies to spin off from the agency's Centers for the Commercial Development of Space.

And that, Rose promises, will make the U.S. pharmaceutical industry "the envy of the world."

FREDERIC d'ALLEST

The Patriarch

"Papa" d'Allest is never more at home than when he is carving the roast caiman—a small, delectable South American crocodile—for his assembled guests at the European Space Agency's launch center in Kourou, French Guiana.

But he also sits at the head of another banquet table—a multibillion-dollar market for the world's communications satellite launch services. And Arianespace, the company for which he serves as chairman and chief executive officer, has quite capably carved out the lion's share of that marketplace for itself.

From September 1987 to June 1989, Arianespace launched 22 satellites into orbit, including 13 in 1988 and half a dozen more during the first six months of this year. The company has a long-standing goal of launching eight Ariane boosters a year, many of which carry more than one payload. That rate must be sustained to work off Arianespace's substantial order book in timely fashion.

As of June, the company had ticketed 72 firm launch orders worth about $4 billion. Remarkably, 11 deals have been signed since January 1988, including probably the most lucrative commercial launch contract of all time: a $300 million pact to orbit three Intelsat 7 satellites, with an option for four more. Arianespace earned $19 million

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TASS/SOVFOTO

Dunayev: Audacious pitchman, abrasive foe

ARIANESPACE

D'Allest: At the head of the banquet table

ALEXANDER DUNAYEV

Moscow's Joe Isuzu

If the Soviet space program made a kitchen sink, Alexander Dunayev would have a deal to sell it, or at least lease it, to you. Cheap.

As head of the Soviet "commercial" space agency Glavkosmos, the aggressive, often arrogant Dunayev says he's willing to consider any legitimate offer from Western customers to buy his country's launch services or rent time on the Mir space station. He's even made an audacious offer to launch sections of NASA's space station Freedom on the mammoth Energiya launch vehicle.

NASA declined, but the offers are getting hard for some concerns in the West to resist. Dunayev's pitch goes beyond the Soviet Union's impressive array of hardware to specials that would make Madison Avenue proud. For $620,000, you can get a three-minute commercial filmed by cosmonauts, complete with your company's logo on their flight suits, launch site billboards and two six-by-nine-foot signs hung on the Mir station.

To the astonishment and dismay of Soviet journalists, Dunayev has even signed up the Japanese to send the first reporter aboard Mir before the end of 1991. Tokyo Broadcasting System will fork over more than $10 million for the privilege—a fact that makes it easier for Dunayev to tune out the protests of his countrymen.

But tuning out journalists is something Dunayev has had some practice with. The one answer he consistently refuses to give is how he got such a

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THE DARING DOZEN

ED KASHI

GEORGE KOOPMAN

Rocket Man

Koopman: Facing down what seem like insurmountable odds

George Koopman won't quit and he won't go away, even in the face of what seem like insurmountable odds.

Koopman has risked everything to validate a whole new solid-liquid fuel rocket technology that he believes will significantly reduce the costs of reaching space. And as president of American Rocket Company (AMROC), the indefatigable promoter has never ceased to push NASA and other government agencies to make it easier for small launch vehicle companies to compete with more established firms in supplying launch services.

Since *Final Frontier* profiled Koopman and AMROC in August 1988, the private launch business has begun to see the transformation Koopman forecast several years ago. A competitor, Deke Slayton, was the first commercial launch contractor to conduct a successful licensed flight, with his Starfire suborbital booster. Not to be left out, Koopman was preparing to fire off *his* first for-hire launch as this issue went to press.

That's not the only change in the past twelve months. When AMROC's supply of a critically needed fuel for its "hybrid" liquid-solid rocket motor was contaminated recently, the company found help from an unlikely ally—NASA. The two have been at odds on numerous occasions over the issue of the space agency's desire to fund AMROC competitors for hybrid rocket study contracts. But when AMROC's contaminated hydrogen peroxide had to be dumped, NASA was the only domestic source to which the rocket company could turn for help. In a matter of days following AMROC's appeal, the agency turned over part of its stockpile of the chemical held in reserve for Scout launches, provided Koopman replaces it.

AMROC's summer launch date remained intact, and Koopman was ecstatic. "This is how it should work between NASA and the commercial sector—they helped us, and we, in turn, helped them. It was a win-win situation."

There have been other victories. NASA's Office of Commercial Programs now looks to fund one or two AMROC launches a year to support experiments sponsored by its Centers for the

Commercial Development of Space. After several lean years, it's now a wide open market for Koopman and his competitors.

The military is doing its share to help, as well. In part due to the efforts of the Defense Advanced Research Projects Agency (DARPA), the Pentagon's think tank, the idea that small satellites could be launched more cheaply on a light launch vehicle than on a large, complicated one is in favor. In January, a Navy contractor gave Koopman's AMROC a contract to develop a restartable kick stage motor for use with a Navy satellite project. Using the hybrid fuel technology of Koopman's larger "Industrial Launch Vehicle," AMROC developed the stage in only seven months.

Money troubles had earlier caused AMROC to bow out of a contract to launch two SDI payloads, but successful completion of the crash program will go a long way to restore AMROC's credibility with the nation's largest launch buyer. None of it came cheap. To arrive at this point—planning a suborbital flight and lacking neither for cash nor customers (so he claims)— Koopman has had to tap investors he's fond of calling "venturesome capitalists." Among the true believers is The Doors' former lead guitarist, Robbie Krieger, and movie star Dan Aykroyd.

And why not? Should the partners in Koopman's venture be any less colorful than the rocket man himself?

CHRISTOPHER KUNSTADTER

The Odds Maker

According to his own bar charts, space underwriter Christopher Kunstadter is an anomaly. He made money in space insurance last year.

Oh, it was only a few million dollars. But the insurance industry has been reeling from a disastrous series of losses that made 1983 the last year with a positive balance on the books.

Other people in the space insurance business make money. Brokers who bring launch vehicle manufacturers and satellite owners together with

Kunstadter: Basic principles and a modicum of luck

underwriters take a commission, whether the launch flops or not. But it's the underwriters who make the launch industry possible in many ways—and they literally have been paying the price.

Without insurance to share the risk, financial institutions wouldn't be willing to lend or invest money in space systems like George Koopman's Industrial Launch Vehicle or James Beggs' Spacehab. There are a few others who share Kunstadter's willingness to underwrite these risky ventures, but the senior vice president for United States Aviation Underwriters, Inc., has something unique to offer the industry: a database.

Armed with his Macintosh and figures going back to the Early Bird communications satellite in 1965, Kunstadter can deliver such frightening statistics as the fact that space insurance losses in the last four and a half years totaled *$584 million*. It could have been worse. If the industry hadn't wised up in 1985 and stopped writing policies with 5 percent and 8 percent premiums, the industry might have ceased to exist.

Premium rates now have stabilized at around 21 percent, where perhaps they should have been all along. "Statistics could have told us that earlier, if we'd been willing to listen," Kunstadter says.

But even Kunstadter admits his success as a profitable underwriter can't be chalked up to statistics alone. He attributes it to "a combination of technical underwriting, basic insurance principles and a modicum of luck."

How much of it is luck? Kunstadter says he can't put a number on his good fortune; it's not a crapshoot. There's an element of real risk analysis, but even those satellites perceived to have the least risk fail. GTE's G-Star 3 was an example. The satellite was built by a reliable manufacturer and launched successfully on an Ariane rocket...and it went awry in orbit.

For that reason, the cash supply for insurance will always be limited. Because the nascent launch service industry in the United States depends on the availability of insurance to cover its flights, it counts on people like Kunstadter to make the right decisions with

THE DARING DOZEN

their available pool of insurance money.

During 1990, more than 20 commercial satellite launches are scheduled, and 60 are planned in the next three years. That's more opportunity for profit for companies like USAIG—but it carries the ever-present risk of loss, as well.

Kunstadter says philosophically, "It's an ongoing business. Presumably, if you lose it one year, you can make it up the next. If you look at this as a year-end business, you could get discouraged. There will always be losses; that's the nature of the business."

BYRON LICHTENBERG

The Go-Between

Byron Lichtenberg knows how important good research is to exploiting the commercial benefits of space. He's been there.

Now chief scientist for Payload Systems, Inc. of Cambridge, Massachusetts, Lichtenberg is a decorated Air Force fighter pilot and an aerospace engineer. In 1983, he flew as a payload specialist on the first Spacelab mission, and has worked since then to develop experimental equipment for other Spacelab flights.

Those experiences taught Lichtenberg that the unique qualities of microgravity sometimes require different hardware than what is generally available to researchers. So in 1984, he and another MIT graduate, Anthony Arrott, founded Payload Systems to provide equipment and services for scientists who have good ideas for space experiments but no idea how to pull them off. Among the equipment Payload Systems offers is a smart sensor that monitors tiny accelerations on the shuttle that might affect sensitive experiments.

But, says Lichtenberg, "It's tough to be a space services company if you can't get to space." So Payload Systems went looking for microgravity flight opportunities to market to the scientific community. Its first offering was a series of flights on NASA's KC-135 weightlessness training aircraft. Customers from all over the world now take advantage of Payload Systems' three annual mission opportunities.

The search for more time in zero-g led Lichtenberg to sign an agreement to fly several protein crystal experiments on the Soviet Mir space station over the next six years, which was

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Lichtenberg: Booking flights for his colleagues and himself

GEOSTAR

Rothblatt: Keeping the dream on track

MARTIN ROTHBLATT

The Lawyer

To Martin Rothblatt, it's not a strange concept at all that the pathway to the planets might begin by trucking grapefruit to Topeka.

Rothblatt heads Geostar, a company committed to launching a satellite system that, along with relaying messages, will provide customers with information on their exact position anywhere on the globe. The concept wasn't Rothblatt's. That honor goes to Gerard K. O'Neill, president of the Space Studies Institute and popularizer/guru of orbiting space colonies.

O'Neill met Rothblatt, then a young Washington, D.C. lawyer, in January, 1983, and retained him to write the FCC application for what became known as the Radio Determination Satellite Service. The idea was revolutionary—all the more so because someone had to find an area in the radio spectrum to accommodate it, *and* the band had to be allocated by the slow-moving FCC bureaucracy.

That the service was approved in only a year is close to a miracle. That a totally new satellite-based communications system could attract $85 million from 800 private investors to get the service off the ground is a tribute both to the genius of its innovation and to Rothblatt's tenacity.

When O'Neill discovered he had a usually terminal form of leukemia, the ailing visionary hand-picked Rothblatt to carry on as president and CEO of Geostar—a succession wholeheartedly endorsed by the bankers who had to pull off the weighty financing for the company's first private offering. There

KATHERINE LAMBERT

were rumors from O'Neill's devotees that the upstart Rothblatt had wrestled the company from his mentor in some kind of palace coup. Both Rothblatt and O'Neill deny the charge.

It hasn't been easy for Geostar's young president to keep O'Neill's dream on track. One of the company's transmission packages (carried on a "host" satellite) failed after launch, and another nearly became a casualty when the G-Star 3 satellite had to expend extra fuel to reach its final orbit. But when the company completed its eighth round of private financing in July 1988 and finalized a $120 million line of credit with a French bank, Geostar had the funding necessary to buy and launch three dedicated satellites by 1993.

The company has begun negotiations with GE Astro-Space to deliver its $160 million worth of hardware under a long-term lease arrangement. The company's first launch—on the shuttle— could take place in 1992. That's right—Geostar's three birds were among the handful of commercial satellites NASA agreed to maintain on its shuttle manifest after the Challenger explosion.

By the first year after the entire constellation of satellites is up, Rothblatt projects revenues topping a half billion dollars a year. Even by last summer, Geostar was raking in $1 million a month from 2,000 customers, including the U.S. Coast Guard, Burlington Motor

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Thompson (center): "I always wanted my own little space program."

DAVID THOMPSON

Top Dog

David Thompson is everything that the aspiring space entrepreneur wants to become. Not yet 40, he now runs Orbital Sciences Corporation, a diversified space company in McLean, Virginia, that had revenues of $60 million last year and may be worth two to three times that.

His motivation? "I just always wanted my own little space program."

At the age of three, Thompson's father took him outside one evening to watch the bright pinpoint of light that was Sputnik 2 flash across the sky. "I knew stars didn't move, and that this was something else," recalls Thompson. "Something special."

His growing fascination for rockets and space led him first to Cal Tech, where he graduated with honors as an aerospace engineer. While still in school he worked at NASA's Langley Research Center for three summers, and later at the Jet Propulsion Laboratory, while Viking was on its way to Mars.

Working at Marshall Space Flight Center on propulsion systems after graduation, he developed an impatience with the space bureaucracy. "When I started at Marshall in '77, the space shuttle was 'two years away' from its first flight," Thompson remem-

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THE REMARKABLE FLYING PANCAKE

Even a ham-handed editor can master NASA's versatile Orbital Maneuvering Vehicle.

ALL PHOTOS: TRW

BY LES DORR, JR.

I was never much good at video games. Somebody else always got Ms. Pac-Man's cherries. Yet here I am, gingerly blipping a joystick in front of the ultimate Nintendo, trying to mate a flying pancake with an iron butterfly.

"Remember, that's a multi-billion dollar space telescope you're docking with," says TRW's Keith Cok over my shoulder. "If you wreck it they'll take all your money, you'll never get another job and you'll be the disgrace of the country!"

Cok (pronounced like the real thing—Coke) merely is trying to instill in me what he playfully calls the "fear factor." Even though this is only a computer-generated simulation, I'm supposed to believe that I'm *really* flying a ten-ton space "switch engine" that NASA prosaically calls the Orbital Maneuvering Vehicle, OMV for short.

The space shuttle does a credible job of placing satellites into orbit, but the spaceliner's ability to maneuver is constrained by the amount of fuel and the weight of the payload it can carry. The OMV, being built by TRW under a NASA contract, will take over where the shuttle leaves off.

Deployed from the orbiter's cargo bay or based at space station Freedom, the OMV will jockey payloads into and out of higher and lower orbits, and will be able to return satellites to the shuttle or Freedom for on-orbit servicing. It can even act as an independent platform for short-term experiments attached to its broad, circular face.

OMV's distinctive pancake shape—15 feet wide but only 5 feet deep—results from the requirement that it fit into the shuttle orbiter's cargo bay while leaving room for other payloads. TRW adopted a modular approach to the space tug's design, incorporating replaceable electronic units, maneuvering thrusters, solar cells and docking gear into a short-range vehicle surrounding a plug-in propulsion module. The propulsion module contains fuel tanks and four throttleable rocket engines for tasks that require greater range.

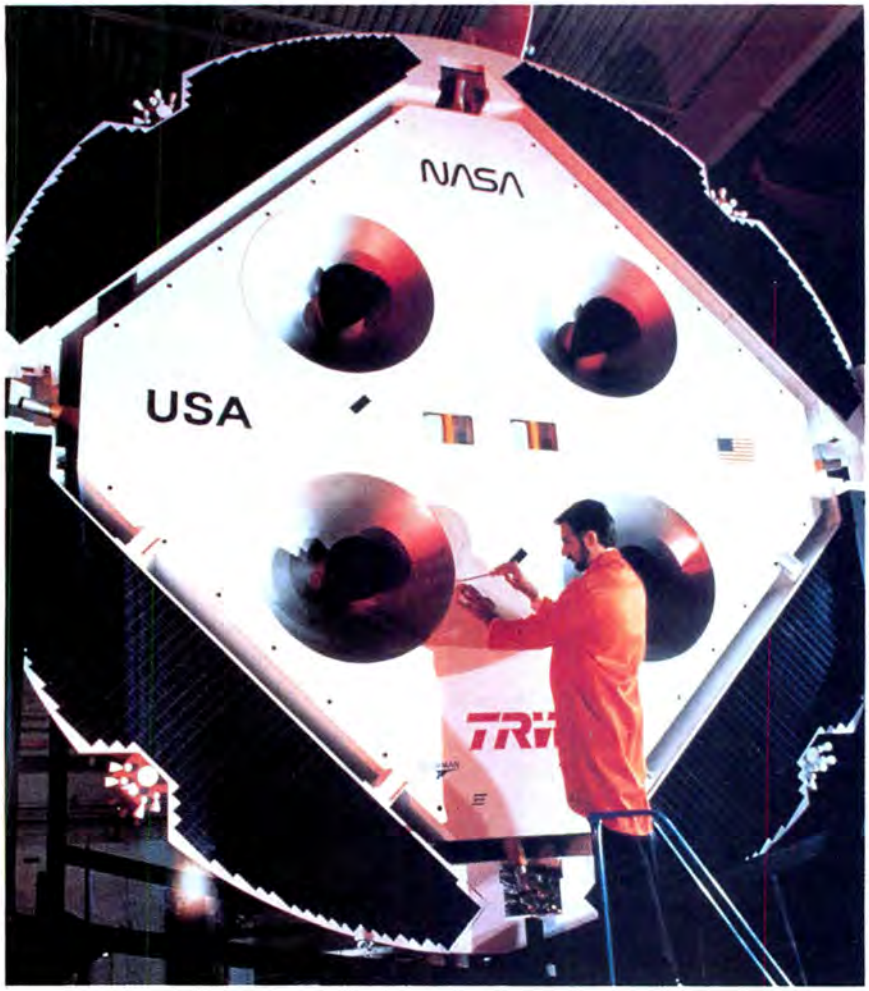
In past American space dockings, at least one of the vehicles had astronauts on board. The OMV, however, will be controlled by operators at Johnson Space Center in Houston. Signals sent from Mission Control will be routed through NASA's communications station at White Sands, New Mexico to a Tracking and Data Relay Satellite (TDRS), which will then shoot the command to the orbiting OMV. But the operator won't know that the space tug has executed the order until the "feedback" signal travels through the network in reverse. The resulting three-second time delay (most of which is attributable to data formatting) proved to be one of the greatest challenges in working out the OMV concept.

"Most people are used to controls where the feedback is in hundreds of milliseconds," says Mack Morrison, TRW's project manager for OMV development. "Three seconds is a time delay which takes a little practice; you've got to anticipate what's going to happen a little bit."

The need for precision flying skills led NASA to another decision: at least on the OMV's first few flights, astronauts will put the spacecraft through its paces. "It was kind of natural," recalls Morrison, who initially was responsible for choosing OMV operators to train. "Once it was decided that Johnson was to be the operating center, it was really hard to argue with the experience that astronauts bring to the table."

Indeed, several groups of astronauts have helped TRW to evaluate and improve the OMV control console. Space veterans like Steve Nagel, Dick Covey, Guy Gardner and the late Dave Griggs have flown easy to difficult test missions, then offered their comments in detailed debriefings.

"It's interesting to watch the astronauts on the OMV," volunteers Keith Cok, who has worked on the project for almost three years. "Other people start whaling away, cruising around



The basic OMV design (opposite and above) can be expanded by attaching special-purpose equipment kits (right).

doing Buck Rogers stuff. Astronauts don't touch *anything* until they know the exact configuration of the OMV—*then* they fly!"

Now, I'm not exactly known for my precision piloting skills. As a kid, I broke the wings off my balsa gliders in record time, and things haven't changed much in thirtysomething years. My daughter's kites, in her father's skilled hands, head unerringly for the nearest tree. Even so, the folks at TRW seemed eager to let me take their flying pancake for a test drive on one of their high-fidelity flight station simulators. They didn't even ask me about a collision damage waiver.

Cok explains that I'll be flying one of the OMV's most important missions, a "re-boost" of the Hubble Space Telescope after its orbit has decayed due to atmospheric drag. As I settle down before the wrap-around console, Cok goes over the functions of the joysticks I've gripped with each hand. The right-

hand controller governs the OMV's position in three axes of movement: roll, pitch and yaw. The left-hand or "translation" stick is what I'll use to move up or down, left, right, forward or back.

Cok also has some sage piloting advice for the neophyte astronaut: "Most people initially tend to fly the OMV like they'd drive their cars, constantly making changes to their steering. If you don't wait three seconds to see what effect your command has, you'll get pilot-induced oscillations. You'll just go back and forth, and totally botch the job."

Thanks, Keith. I needed that.

My approach begins about 15 feet away from the space telescope, whose cartoon-like image fills half my screen. To move in, at Cok's suggestion I input five thruster pulses with the translation controller. Three seconds later, a tiny indicator light flashes and my "X-Axis" (forward and backward) display counter clicks off five times to tell me the OMV has done my bidding.

And nothing happens. Uh, Keith, shouldn't we be moving about now?

I've learned one of the immutable laws of space operations: When you give a few 150-millisecond pulses of gas to a 20,000-pound vehicle, you just don't go zooming through the wild black yonder. "I have more excitement watching my grass grow," Cok jokes.

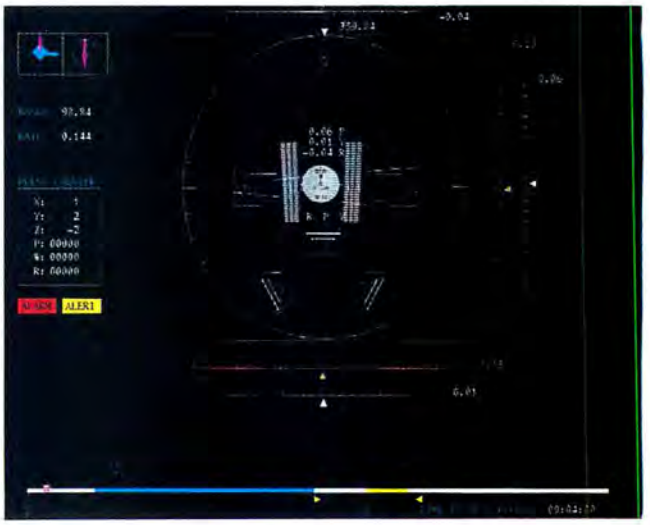
There's a good reason why the OMV is such a dog in the acceleration department. The space tug must dock with Hubble at a very low relative velocity—Cok says operators shoot for *two-hundredths* of a foot per second—to avoid creaming the telescope's delicate scientific insides. Even OMV's four main engines are relatively gentle, since Hubble's large solar arrays, which will remain deployed as the OMV pushes it around the sky, can't tolerate high acceleration rates.

After a minute or so, the docking target on the space telescope finally nudges ever-so-slightly closer in my "near-field overlay," a large rectangle with vertical ticks to tell me when the satellite is ten, five and three feet away. At this distance, flying the OMV is an eyeball operation, since the spacecraft's radar becomes ineffective within about 35 feet of the target. Cok remarks that I seem to be rolling slowly, and suggests that I command the OMV into "attitude hold" so that the vehicle's thrusters will lock it into position relative to Hubble.

I've also managed to drift somewhat below the target, so at Cok's urging I input five pulses upward through the translation joystick. As the docking bar once again becomes centered, Newton's Third Law comes into play: to stop my "action" upward, I need an equal but opposite "reaction" of five pulses down. Blip-blip-blip-blip-blip. Three seconds later, five grateful acknowledging blinks of the thruster light.

Look, Ma, I'm an OMV pilot!

Ah, but I haven't earned my wings *yet*. Somehow (dammit, I didn't do anything) I've drifted to the right, and Cok kindly advises one tweak to the left. I'm



learning. The docking overlay slowly centers up, and I blip once to the right to stop my leftward movement.

As the OMV zeroes in on Hubble, Cok highlights some of the other displays that I've so far blissfully ignored. A clever graphic representation of orbital events is just below my viewscreen. A tiny pink square (the OMV) crawls along a timeline that glows white where the spacecraft is in daylight, dark blue for the nighttime part of the orbit.

A blue triangle indicates the point at which "handover" between the TDRS-West and TDRS-East tracking satellites occurs. It's a crucial time; for about a minute, the OMV is out of touch with the ground. No video, no commands, zip. "You don't want to be involved in a critical maneuver just then," Cok notes dryly.

I'm within three feet of the target, and the damned thing won't stay still! The OMV is gently gliding down and to the left. I blip right once, and at Cok's prodding, twice up. There we go! To fine-tune my approach, Cok also tells me to switch to short-pulse mode on my thrusters. Now they'll fire for only 50 milliseconds, giving me even more delicate control. Easy...two pulses left... wait the three seconds...one right....

Suddenly Cok interrupts my concentration with a warning: "Looks like you've got a pitch."

I'd assumed that I was coming in to Hubble straight up, since I had commanded the OMV into attitude hold many minutes ago. But now the pancake is leading with its bottom edge. Cok assures me that it's not anything I've done—nor has the OMV changed position. It's that big fat target out there. The space telescope is so massive (44 feet long, 25,000 pounds) that Hubble itself has been minutely torqued around by Earth's gravity field during the relatively short time involved in my approach. (And I have new respect for this simulator.)

Simulator guru Keith Cok pilots the OMV control console. Above, the OMV zeroes in on Hubble.

Cok suggests we try what he characterizes as a "fairly complicated" docking. We'll try to latch on to the two bottom trunnions on the satellite's three-point docking gear, close the OMV's grapples, then pitch up and grab the mechanism at the top. Contact! OK, we're hooked up at the bottom. Let's get that third latch.

The right-hand joystick comes alive as I switch off the attitude hold function. I'm cookin' now. One blip to slant downward...one more...chase it...c'mon you mother...indicator's in the green...close grapple ...DOCKED!

Well, almost. Cok reminds me that at this point the trunnions are still just rattling around in the latches. I fire off the command to "rigidize," or hard-dock. Three seconds later, the console light tells me I've pulled off a successful mission.

If this were the real OMV and the real HST (somebody once suggested NASA should put out a BOA—Book Of Acronyms), we'd crank up the thrusters and spend hours pushing Hubble back where it belongs. As it is, another would-be birdman is waiting in the wings for a training lesson, so I merely unlatch from the space telescope, and drift away with a few backward pulses.

NASA already has booked the Orbital Maneuvering Vehicle for a test and demonstration mission aboard the shuttle in October 1993. Under the current flight plan, OMV will pull the SPARTAN astronomy sub-satellite out of the orbiter, release it some distance away, then use the mini-observatory as a target for stationkeeping and docking. As a bonus, the OMV will have a hitchhiker: a deployable antenna associated with Canada's Waves in Space Plasma (WISP) experiment will be cantilevered to the front of the spacecraft.

Even as TRW prepares to cut metal for the Orbital Maneuvering Vehicle next summer, NASA and commercial customers are thinking of new ways to use the all-purpose spacecraft. Preliminary studies at Marshall Space Flight Center in Huntsville, Alabama suggest that the OMV could stabilize space station Freedom during the earliest stages of its construction. Users who are considering putting instruments on the station's co-orbiting platforms take OMV for granted as "part of the infrastructure," says TRW's Morrison. And Global Outposts, Inc., a company that wants to convert the shuttle's discarded fuel tanks into simple science platforms (*Final Frontier*, February 1989) has been discussing the use of OMV as a logistics vehicle.

I'm not thinking quite that far ahead as the OMV and Hubble and I part company, but I wistfully put myself at Johnson Space Center five years or so from now. A pair of astronauts is flying the pancake from two side-by-side consoles. Suddenly, one of them coughs, turns green and collapses, a victim of one too many Diet Cokes. A frenzied call goes out from the frantic OMV flight director: *Quick, somebody man that station!!!* Video game freaks, eat your hearts out. □

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Off the Shelf and Int

More and more, space station engineers are shopping for the blue-light special.

When the Soviets needed a television for the Mir space station, they did the same thing that many an American consumer would do—they bought a Sony. According to French "spationaute" Jean-Loup Chretien, who visited Mir last year, the Russians flew the television without modifications, even leaving the outer cabinet unchanged.

Neither the Soviet nor the American space program has yet reached the point where all spacecraft electronics can be bought at Radio Shack, but the trend toward using off-the-shelf technology for spaceflight operations whenever possible is very strong. According to James Ragan, a flight equipment manager at NASA's Johnson Space Center, approximately half of the items that have no influence on mission success or crew safety ("Criticality 3," in shuttlespeak) are bought in ordinary stores and repackaged or modified for use in space. That includes equipment such as extra cameras, vacuum cleaners and calculators, and even more mundane items like food snacks and t-shirts.

Because these off-the-shelf products have been developed for the American consumer and not for the space program, they don't have to follow the same rigorous documentation and testing protocols imposed on space hardware. In fact, items under $2,500 can simply be bought on NASA's charge account, which avoids time-consuming, paperwork-intensive government procurement procedures. But off-the-shelf goods must still come up to strict standards and pass certain essential tests before they can be flown into orbit.

"First we have to look at the job we want to do in orbit," explains Ragan. "Then we write up a list of specifications and look around on the market to see what's available."

Sometimes there's a wide choice of products. For instance, when NASA went looking for a small, powerful battery-driven vacuum cleaner, the agency found three or four different brands that might work. These were sent to a laboratory in White Sands, New Mexico to test for flammability and "outgassing"—the escape of gases from materials in the vacuum of space.

If an item has electronics, it's often subjected to electromagnetic testing to see if it needs to be shielded. The much-publicized Sony 8-millimeter camcorder flown aboard Atlantis last May was just one of several NASA is testing. "We might fly a VHS format another time and try several different brands," Ragan says, "to see which is best for orbital conditions."

Personal hygiene items have proven especially troublesome to modify for orbital use. Many cosmetics contain alcohol, which can be a serious problem in the closed atmosphere of a spacecraft or space station. "Alcohol evaporates in air," explains Rafael Garcia, a NASA systems integration engineer. "On the space station, we'll be extracting water from the moisture in the cabin atmosphere. You can't remove the alcohol from the cabin air, so pretty soon the alcohol levels will get too high."

Simple grooming practices like taking a shower and washing one's hair are essential for good health on long space flights, but they pose terrible practical problems in a gravity-free environment. NASA tested four methods to wash hair in space: a shower cap, a dry wipe, a wet wipe and a polyester wet-sponge. Subjects came into the Johnson Space Center lab every other day with dirty hair, used one of the products, then filled out a questionnaire.

The shower cap, which fed water in and out, required users to suction the soap off. It turned out to be "not too good," according to Phyllis Grounds, the subsystem manager for space station hygiene. The dry wipe was derived from a failed Colgate product, a comb developed to remove grease and oil from the hair...which, alas, was marketed during the "greasy look" 1950s. The NASA guinea pigs found that the dry wipe did a good

job of removing oil, but not of cleaning the hair. A chemical-infused sponge, similar to those used in hospitals and prisons, was beaten out by the wet wipe, which was easy to use and which seemed to clean the hair satisfactorily.

After toxicity and flammability tests, simulations onboard zero-g training aircraft and an initial trial on last December's classified shuttle flight, the wet wipe became a popular item in crew members' personal hygiene kits. "Just about everybody uses them now," says Garcia. They'd better; NASA bought 40,000 of them.

Developing a shower for the NASA/international space station

o Orbit

BY ALCESTIS R. OBERG

Freedom has been quite a bit more complicated. During the 30-day ground testing period, subjects either hated or loved the shower initially. "But after two or three days, they began to shut off their judgment and became more indifferent to it," says Garcia. "By seven to ten days, they had adapted to its unfamiliarity." NASA tested the shower prototype on the KC-135 zero-g aircraft last year. It hasn't yet been tested in space.

Because the shower is part of a tightly closed system, astronaut satisfaction isn't the only problem. NASA may use an Air Force apparatus to separate air from water in the shower atmosphere, and then pump them back into separate recycling systems. Commercial defoamers used in chemical

TOM R. GARRETT

plants and restaurants may be adapted to filter the shower's used water before further processing.

But the space agency very likely will have to develop its own very pure brand of soap, limited to four or five prime ingredients. Although it probably would be too expensive for the current cosmetics market, the NASA soap may even become a spinoff someday, if the U.S. cosmetics industry becomes more ecology-minded.

Even now, cleansers and household disinfectants are being analyzed for their long-term "environmental impact" onboard spacecraft with closed systems. The household products market abounds in exciting, clever and useful possibilities for space station interiors; for example, NASA is considering ceramics impregnated with biocides (originally developed for hospital use) so that germs die on contact with the surface.

Sometimes, the agency's hardware problems are solved unexpectedly by a kind of reverse spinoff from marketplace to space. Consider the search for the perfect shaver. In the early days, NASA fooled with vacuum-cleaner shavers for male astronauts, so their beard stubble didn't get loose in the spacecraft cabin. When these failed, astronauts reverted back to old-fashioned suds and razors, but complained that shaving was still a mess and that towels used to dry off became a smelly storage problem. Some astronauts gave up and just grew beards. Fortunately, the microscreen shaver put an end to the problem. Microscreens catch hair stubble, and the shavers are light, easy to use and easy to clean.

Off-the-shelf technology sometimes comes from the Pentagon's warehouses, too. Military items are usually built to rugged specifications very similar to NASA's, and have similar toxicity and flammability standards for their materials. A sturdy teleprinter from an Army command jeep was modified to become the shuttle teleprinter, and the "heads-up" display technology in military helicopters and planes wound up in the shuttle's forward windows. Similarly, "heads-up" helmets now being used in some military aircraft may be transferred into a NASA spacesuit helmet someday so that checklists and other vital information can be displayed right before a spacewalker's eyes.

Probably no industry advances have affected the space program more than those involving food technology. New packaging, convenience foods and fast-cooking equipment have all made mighty contributions to NASA's efforts in human space flight.

"All snacks and cereals are off the shelf," says Mike Fohey, a principal engineer in food systems at Johnson. "Nuts, M&M's, Lorna Doones, Frosted Flakes and granola are all bought at the local Kroger and then repackaged in our pouches."

The pouches are made of a clear plastic laminate, but they're tougher and sturdier than Ziploc bags. The food is vacuum-packed in nitrogen, which provides smaller volume storage and preserves freshness. The plastic packaging is impermeable to gas and moisture from outside, unlike most commercial bags.

Lunch and dinner entrees, however, are still specially prepared for astronauts. The Department of Defense "meal ready to eat" rations have been added to the freeze-dried shuttle fare, but because water will be in much shorter supply on the space station than on the shuttle, NASA's grocery shoppers will have to do away with freeze-dried food and stock up on microwavable frozen entrees, already so popular in American homes. Microwave meals generally are quick, tasty, easy to use, offer a huge variety of choices and can be completely consumed at one sitting—perfect for a space station larder with eight hungry, time-driven astronauts and no mom.

The wet wipe became a popular item in crew member's personal hygiene kits. "Just about everybody uses them now," says Garcia. They'd better; NASA bought 40,000 of them.

▼ ▼ ▼

"The space shuttle is a lot like camp," quips Fohey. "The space station will be more like home."

Unlike the food, the ovens probably will be made specially to NASA specifications. "The shuttle convection oven was not off the shelf," Fohey points out. "It required a special configuration to fit into the shuttle mid-deck galley, and all sorts of restraints, like special racks inside to keep the food from floating around."

The U.S. clothing market isn't up to NASA standards in most cases, either. Synthetic fabrics can outgas like crazy, and most aren't rugged enough for orbital work. Except for 100 percent cotton t-shirts, bike trousers and rugby shirts purchased from ecology-minded Land's End (and some female bras and panties, which NASA would rather write waivers for than to make the subject of intimate, potentially embarrassing research), almost all space clothing is expensive and specialized government-issue stuff. This includes launch and landing garments, rugged flight jackets (which cost several hundred dollars each), and naturally, the pressurized space suits.

Jennifer Noelke, a NASA piloted systems engineer, said the space agency's clothing specifications include "low lint, double and triple stitching on seams, sturdier-than-usual zippers, and very, very tough pockets." Even the NASA pocket designs are complicated: "One pocket is designed to carry only a Swiss army knife—very tightly. Some pockets have pockets within pockets so items can be separated, secured and retrieved," explains Noelke.

When it comes to clothing, waistbands and fabrics must accommodate the changes in body measurements that result from fluid shifts in weightlessness. "The chest material has to be able to accommodate a nine-inch chest expansion," says Noelke, "and there are big back pleats in the jackets so the arms can reach up comfortably while the body is anchored to a foot restraint." The waistbands are elastic enough to handle the inevitable belly-expansion that takes place on the return to Earth, when fluids head back down into the lower part of the body.

Noelke hopes that in the future, NASA astronauts can be "on the frontier of fashion too—in clothes that look good and feel good, and aren't antiquated." A less unisex emphasis might also be in order: clothing that openly acknowledges and accepts women's larger hips, smaller waists, bigger breasts and narrower shoulders, and doesn't just try to stuff the female form into NASA's male-proportioned flight suits.

A few companies assist the space agency by modifying their products to ease the process of transferring items into orbit. They provide schematics of their mechanical and electronic products, or they alter their manufacturing process slightly with a product headed for space. For instance, one factory left the "baby" fragrance out of the astronauts' facial wet wipes at NASA's request.

Some of these companies go all out,

continued on page 61

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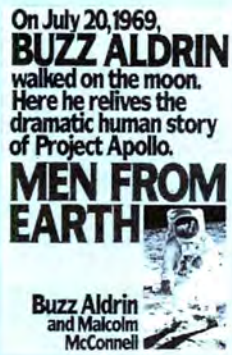

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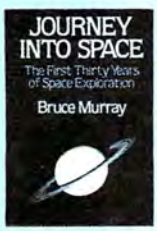

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THE PRIVATE VECTOR

Stretching the Shuttle

The new, souped-up orbiter will be racking up extra hours in space by 1992.

▼ ▼ ▼

By Beth Dickey

While a frustrated NASA counts its change, trying to gather enough coins to build a permanent motel in Earth orbit, it will have to settle—at least in the early 1990s—for a motor home. That near-term solution is called the Extended Duration Orbiter, a shuttle that can stay in space for as long as a month while its crew works in microgravity.

Congress has discovered that you can soup up a shuttle for a fraction of the cost of building space station Freedom. So NASA is equipping two orbiters—reluctantly, according to some—to fly missions ranging from 16 to 28 days. Currently, the shuttle's onboard supply of fuel and other "consumables" limit it to seven to ten days in orbit.

"NASA has sort of been dragged kicking and screaming in that direction," asserts Rep. William Green, D-N.Y., the ranking Republican on the appropriations subcommittee responsible for the civil space budget in the House.

Without owning up to tantrums, managers of NASA's Extended Duration Orbiter (EDO) project admit to worrying that a stretched shuttle could be seen as an alternative to the space station.

"The official position is that we're going to make a 16-day orbiter," says Bill Ayotte, who oversees the shuttle upgrade from NASA headquarters in Washington. "The problem is, the orbiter wasn't designed to stay in orbit a long time. Just off the cuff, I think maybe it is seen as a cheap replacement for other things that NASA wants to get involved in."

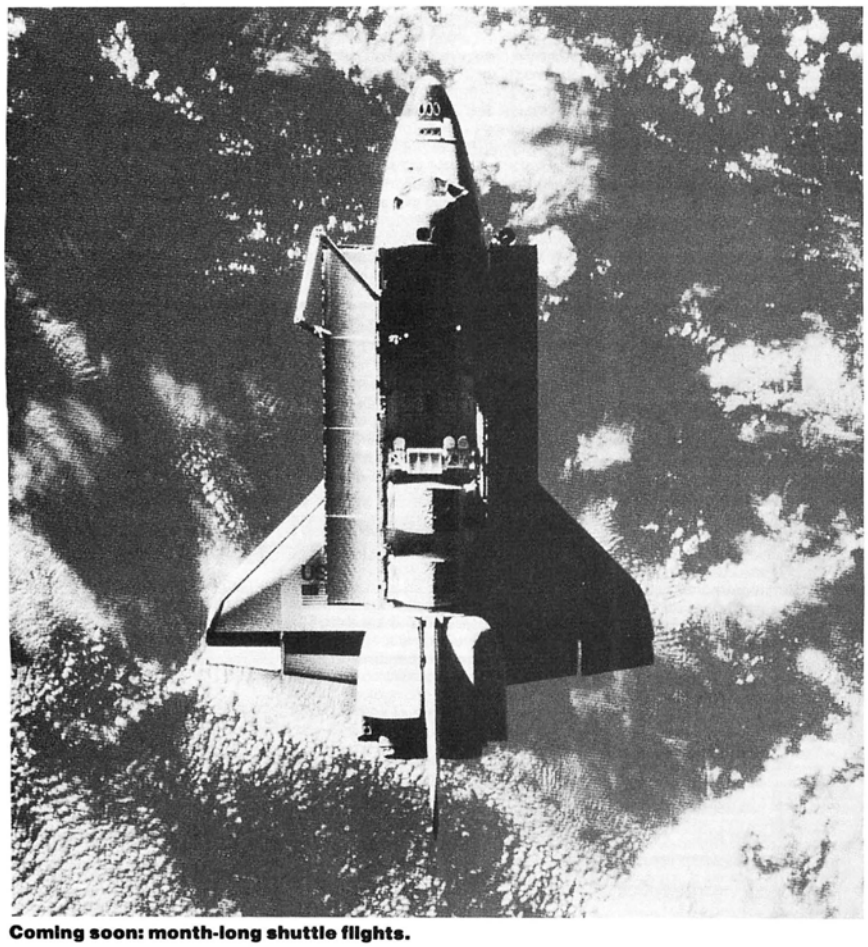
There are other, more technical issues that also will need to be resolved before NASA flies 28-day missions. One concern is the ability of shuttle pilots to land an orbiter safely after spending a month in weightlessness. Storage space may also be a problem on a vehicle designed for week-long flights, and some experimental equipment—animal holding facilities, for example—were not built with 28-day missions in mind.

Two EDOs will cost only a little more than $200 million. The first extended mission on NASA's launch schedule is in March 1992, when Columbia is scheduled for a 13-day flight with the U.S. Microgravity Laboratory—a facility dedicated to materials science experiments—onboard.

In order to extend its capabilities, Columbia will be grounded in 1991 for a seven-month makeover. NASA is paying shuttle manufacturer Rockwell International $126 million to install EDO "kits"—a larger latrine, improved air conditioning and several extra pairs of storage tanks for the cryogenic hydrogen and oxygen that produce electricity and water.

Always short of cash, NASA may "privatize" the same modifications on the replacement shuttle Endeavour, which is now under construction. Rockwell is fitting the new orbiter with plumbing and wiring that will make it easy to install EDO kits later. But instead of buying the kits, NASA is negotiating a deal to rent them from Rockwell.

However, the plan to lease the equip-



Coming soon: month-long shuttle flights.

ment from the private sector has a long way to go, Ayotte admits. "Obviously, because of what happened on 51-L (Challenger), the agency is more concerned about flight safety issues," he explains. "To go out and have [the EDO kits] produced by some independent function outside of NASA's control raised some eyebrows."

Equipping the shuttle for longer trips in space isn't a new idea. Years before the Challenger explosion, NASA thought it would be nice to have an orbiter that could stay in space for longer than a week, in order to give scientists more time to experiment in microgravity. But when the space station project was born in 1984, the agency dropped plans for an extended duration orbiter.

In 1985, with the station already in funding trouble, NASA was ordered by Congress to reconsider the idea of an EDO. Shocked by the shuttle disaster and a sudden requirement to justify sending humans into space, the agency reported to Congress in 1987 that an EDO would help relieve some of the pressure NASA was under to orbit a small, privately developed laboratory known as the Commercially Developed Space Facility, or CDSF.

Some members of Congress, like Green, thought a CDSF was a thrifty alternative to the space station until last April, when the National Research Council released a report predicting that even with NASA as a guaranteed customer, a CDSF would not be able to drum up enough business. The council declared that all of the experimenting and manufacturing planned in microgravity for the foreseeable future—at least until the late 1990s, when the space station is scheduled to open for business—could be done onboard an Extended Duration Orbiter.

Whether the council's market study is on target remains to be seen, Ayotte challenges, but he agrees with the advice.

"In the big picture, EDO does seem to be a logical way to get some early knowledge about the stuff you'd eventually want to run on the space station," he says. □

BOUNDARIES

The Road Not Yet Taken

There's still one more world to conquer

▼ ▼ ▼

By Ray Spangenburg and Diane Moser

If you listen to a group of some 20 astronomers who call themselves the "Pluto Underground," they'll say the time has finally come to mount an expedition to the farthest known planet.

Now that Neptune has been reached by Voyager 2, only icy Pluto, orbiting between 2.74 and 4.7 billion miles from Earth, remains unvisited by NASA's robotic explorers. And these young and energetic scientists think it begs for a mission.

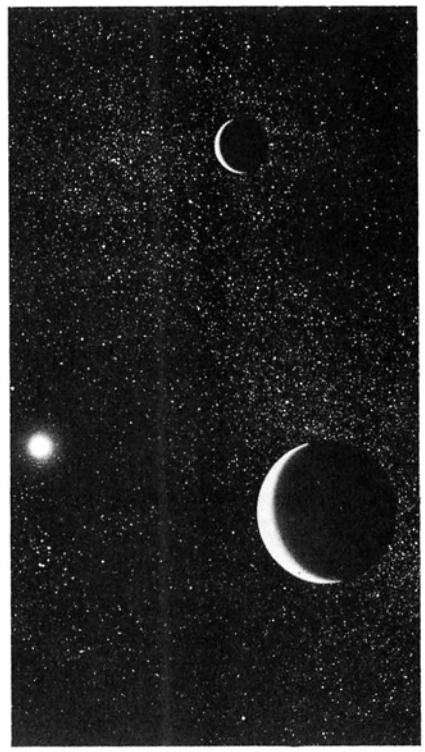
"It's the Everest of scientific exploration of the planets," says Alan Stern of the University of Colorado's LASP (Laboratory for Atmospheric and Space Physics). "It is the rockiest known object in the outer Solar System. It is the smallest planet. It's the coldest. And it's the only double planet," he adds. The relative size of Pluto's satellite Charon (nearly half as large as the planet), says Stern, makes the pair a sort of planetary analogy to a binary star.

Even though Pluto and Charon are now at their closest distance to Earth since George Washington was chopping cherry trees, they still appear in telescopes as little more than faint spots of light. Made from the same material as the giant outer planets, they are thought to be nearly pristine samples of the stuff from which the far Solar System was formed.

During this relatively close approach to the Sun, observers have the rare opportunity to watch the collapse of Pluto's atmosphere. Planetary scientists expect that the tenuous atmosphere will begin to fall in upon itself, comet-like, as Pluto's orbit swings away from the Sun again.

But close as Pluto currently is to Earth, it's not close enough for members of the Pluto Underground. The scientific return from a mission to actually visit the icy world, say NASA planetary science advisers Mike Drake and Dave Morrison, would be great. In fact, the idea has come under serious consideration for a proposed "new start" in NASA's 1993 budget.

A Pluto mission could make use of the Mariner Mark 2 Voyager-type spacecraft in order to keep costs under $500 million (the 1976 Viking Mars mission would cost $4 billion in today's dollars).



Artist's view of Pluto and Charon, the Solar System's only double planet.

"But with no data return until 2014," says Drake, "we don't think we could get it through Congress right now." Could engineers keep instruments functioning in the space environment over a 25-year span? Could we keep Congress interested that long? And how many scientists would gamble their careers on a mission they might never see arrive?

These worries make it likely that other projects such as the Lunar Observer or a comet sample return (perhaps in collaboration with the European Space Agency) will fit in sooner to NASA's agenda for exploration. Near-Earth asteroids are another high-interest target, adds Morrison. So practicality may bump Pluto down the queue for now — especially since future advances in propulsion technology might still get a mission out to Pluto by 2014 or 2020, even with a later start.

Not to be defeated, though, the members of the Underground, who are mostly in their early to mid-thirties, maintain they are ready for a long fight. And they continue to explore alternative means of reaching their destination.

It would be possible, for example, to piggyback a small, inexpensive spacecraft on another vehicle. A mission called Solar Probe, says Stern, planned to head deep into the Sun, would first have to slingshot around Jupiter, and a Pluto mission could ride along to slingshot outward in the other direction. Another possible carrier would be a probe headed into the atmosphere of Jupiter itself. Even a dedicated Pluto mission could be launched as late as 2001 (instead of in 1997, as the proposed 1993 start calls for) and sent past Jupiter for a gravity assist on its way to the edge of the Solar System.

The job could be done, says Stern, for as little as $55 million, with a barebones spacecraft and little redundancy. Such a mission might only have an 80% chance of making it, but the cost could be kept relatively low, and we could still get there in time to observe the rare process of atmospheric collapse. Of course, more could be done with a $500 million mission, and, Stern points out, there are many opportunities for international collaboration and shared costs.

The thing to remember, says Stern — who has just been granted viewing time using the Hubble Space Telescope to map the surface of Pluto — is that first-time looks at the planets have always been more exciting than we expected. And Pluto is sure to be no exception.□

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GLOBAL CURRENTS

Leader of the Pack

Igor Volk, chief test pilot for the Soviet shuttle

▼ ▼ ▼

By Les Dorr, Jr.

Celebrity doesn't seem to sit well on Igor Volk's stocky shoulders. Even as he gives a courteous, carefully considered answer to my question, he seems uncomfortable with the whole idea of being interviewed. I can almost hear the wheels turning in his head: Stay up in Mir for a year and they give you flowers, kisses, Orders of the Red Whatever. Help develop the new space shuttle Buran, and you get saddled with *amerikanskii zhurnalist*.

Thanks, comrades, I'd rather be flying.

By now, Volk should be used to reporters. He was a cosmonaut-researcher on the Soyuz T-12 mission in 1984, during which he spent 11 days performing experiments onboard the Salyut 7 space station. The red-headed graduate of the Moscow Aviation Institute also has flown two dozen approach and landing tests of the Soviets' jet-powered shuttle trainer, making him titular head of the "Wolf Pack," the cadre of pilots now training to fly Buran and its sister ships into orbit. (*Volk* is Russian for "wolf.")

Volk eventually may rank up there with cosmic heroes like Gagarin and Leonov. He's been tapped to command Buran's first piloted voyage, scheduled for 1992—*if* the program stays on track. But Soviet space efforts, particularly the costly, high-profile shuttle project, have suffered an unprecedented bashing in recent months from the Soviet media. The program's detractors sing a tune that sounds all too familiar to Americans: What good are space spectaculars when the Motherland still has so many Earthly problems?

"Look, if someone wants to criticize something, they should criticize the people who are doing the program, not the program itself," Volk—no longer aloof—says heatedly through his interpreter. "Besides, you can't stop progress; the program is going to continue in any case. And if the public is told what our goals are, and can see that they are being implemented—then the criticism will stop."

Yet Volk is rather cagey when it comes to explaining exactly why the Soviets need a high-priced, reuseable shuttle. He maintains that the Soviet Union will continue using "ordinary rockets" to put satellites into orbit. "Presumably," he says (shouldn't the shuttle's chief test pilot know for sure?), Buran's main purpose is to return unspecified objects from space, since "there's no other way to do it."

Concerning plans for the Soviet shuttle's first few piloted flights, Volk becomes more expansive. The mission he'll command in 1992 simply will test whether the orbiter is spaceworthy with people onboard ("That's how the Americans saw it, too," he adds) and will involve only himself and a copilot, as yet unnamed. Later voyages, says Volk, will have three, then five and eventually seven crew members.

Volk is really in his element when he tackles the nuts-and-bolts aspects of the Soviet spaceliner. Perhaps it's his background; he's been a test pilot for nearly a quarter-century, and has flown just about everything the Soviet Union has to offer while amassing more than 4,700 hours in the air. He's also one of only two people (Anatoli Levchenko, who died from a brain tumor last year, was the other) known to have participated simultaneously in both the shuttle and Soyuz programs.

TASS/SOVFOTO

Volk in Soyuz cosmonaut regalia. His next ticket to orbit is a first-class seat on Buran, circa 1992.

"Makes my life a little complicated, but I still enjoy it," Volk grins.

His description of Buran's crew cabin sounds remarkably like the accommodations on NASA's shuttle orbiters. The vehicle is divided into a flight deck/cockpit and a lower area where cosmonauts will sleep and set up experiments. One notable difference is that Buran's airlock for spacewalking cosmonauts will be in the orbiter's cargo bay, a change Volk credits to his American counterparts:

"In [your] shuttle, the airlock intrudes into the living area and takes up a lot of useful space," he says. "The astronauts suggested strongly we should avoid that."

The traditional Soviet approach in returning piloted spacecraft to Earth relies almost exclusively on automatic systems, with cosmonauts acting only as emergency back-ups. Volk insists that he has "no objection to an automatic landing," but wants the ability to take over during the final approach to the runway. "In Buran, I have the controls—but I don't yet have the necessary displays," he laments, passing off the problem as "the sort of doctrinal quarrels that cosmonaut-pilots have with the engineers."

Volk doesn't expect to make another Soyuz flight, so his next trip into space won't come until Buran thunders aloft from the Baikonur Cosmodrome three years from now. As the seconds tick down to ignition of Buran's mammoth Energiya booster, will the pilot who knows the shuttle better than anyone have second thoughts about pulling off a successful flight?

"Don't worry," Volk chuckles, "if I have any doubts—I'm not going to be there!" □

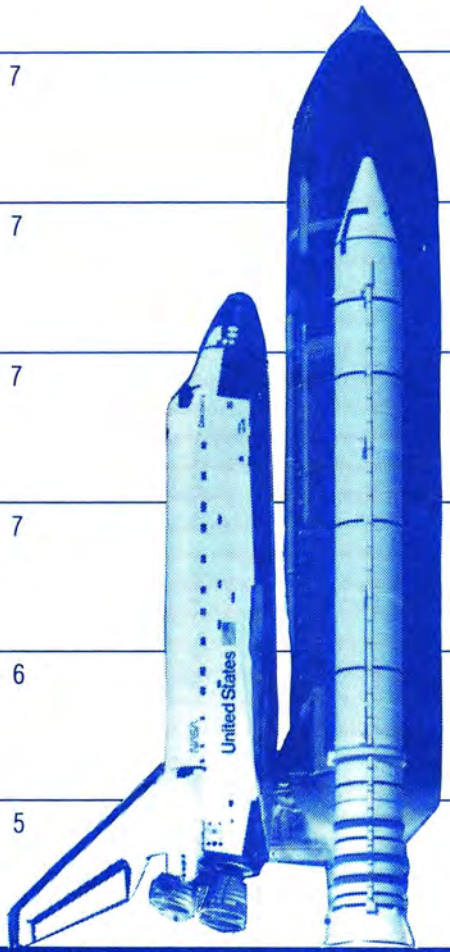
DATA BASE

Space Shuttle Launch Schedule

(October 1989 through December 1991)

Flight	Orbiter	Crew (Names if Assigned)	Launch Date	Mission Duration	Orbital Altitude	Primary Cargo
34	Atlantis	CDR: Donald Williams PLT: Michael McCulley MS: Shannon Lucid Ellen Baker Franklin Chang-Diaz	10-12-89	5 days	160 mi.	Galileo probe to Jupiter
33	Discovery	CDR: Frederick Gregory PLT: John Blaha MS: Story Musgrave Kathryn Thornton Manley Carter	11-19-89			Classified military flight
32	Columbia	CDR: Dan Brandenstein PLT: James Wetherbee MS: Bonnie Dunbar David Low Marsha Ivins	12-18-89	10 days	190 mi.	SYNCOM 5 Retrieval of Long Duration Exposure Facility (LDEF)
36	Atlantis	CDR: John Creighton PLT: John Casper MS: Dave Hilmers Mike Mullane Pierre Thuot	2-1-90			Classified military flight
31	Discovery	CDR: Loren Shriver PLT: Charles Bolden MS: Steve Hawley Kathryn Sullivan Bruce McCandless	3-26-90	5 days	310-330 mi.	Hubble Space Telescope
35	Columbia	CDR: Vance Brand PLT: Guy Gardner MS: John Lounge Jeff Hoffman Robert Parker PS: Ronald Parise Samuel Durrance	4-26-90	9-10 days	190 mi.	ASTRO-1 ultraviolet telescopes Broad Band X-Ray Telescope
37	Atlantis	CDR: Steve Nagel PLT: Kenneth Cameron MS: Jerry Ross Jerome Apt Linda Godwin	6-4-90	5 days	243 mi.	Gamma Ray Observatory
38	Discovery	CDR: Richard Covey PLT: Frank Culbertson MS: Robert Springer Carl Meade Charles Gemar	7-9-90			Classified military flight

Flight	Orbiter	Crew (Names if Assigned)	Launch Date	Mission Duration	Orbital Altitude	Primary Cargo
40	Columbia	CDR: Bryan O'Connor PLT: Sidney Gutierrez MS: Rhea Seddon James Bagian Mae Jernigan PS: F.D. Gaffney Robert Phillips	8-16-90	8-9 days	160 mi.	Space Life Sciences Laboratory
41	Atlantis	5	10-5-90	5 days	160 mi.	Ulysses solar probe
39	Discovery	MS: Guy Bluford Richard Hieb Charles Veach CDR, PLT and two MS to be assigned later	11-1-90	8 days	140 mi.	Infrared Background Signature Survey CIRRIS SDI experiment
42	Columbia	MS: Mary Cleave Norm Thagard CDR, PLT, one MS, two PS to be assigned later	12-6-90	9-10 days	160 mi.	International Microgravity Laboratory
43	Atlantis	5	1-31-91	5 days	160 mi.	Tracking and Data Relay Satellite
44	Discovery	5	3-4-91			Classified military flight
45	Columbia	7	3-28-91	9-10 days	160 mi.	Atmospheric Laboratory for Applications and Science
46	Atlantis	7	5-16-91	7 days	160 mi.	Tethered Satellite System EURECA retrievable carrier
47	Discovery	7	6-17-91	7 days	160 mi.	NASA/Japan Spacelab flight
48	Atlantis	7	8-22-91	7 days	175 mi.	Starlab DoD Spacelab
49	Discovery	6	9-30-91	7 days	160 mi.	Laser Geodynamics Satellite Geostar-1
50	Atlantis	5	11-27-91	5 days	291 mi.	Upper Atmosphere Research Satellite



CDR: Commander; PLT: Pilot; MS: Mission Specialist PS: Payload Specialist Note: NASA retains the original mission number even when flights are launched out of sequence. All dates are subject to change.

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REVIEWS

The Emigrant Trail
By Michael H. Smith
General Dynamics
Space Systems Division P.O. Box 85990
San Diego, CA 92138
130 pages. $4.90,
plus $1.50 for shipping and handling

By Jack D. Kirwan

The only problem with reviewing this book is whether to give greater praise to the contents or to the format. Both are highly original, conveying the vision and the technological possibilities of a spacefaring civilization better than anything that has come along in years.

In size, shape and design, *The Emigrant Trail* mimics that venerable institution of the American coffee table, the *National Geographic*. Only this special issue of *Planetary Explorer* (the magazine of the "Planetary Exploration Society") is dated December 2038, and is devoted to the first commercial spaceflight to Mars. The idea is so simple, yet so effective, that you wonder why it was never done before.

You won't find *The Emigrant Trail* in your local bookstore. It was conceived and produced by the Marketing Communications branch of the General Dynamics Space Systems Division in San Diego, which, according to the title page, is distributing the book "as an educational and informational journal with the sole purpose of stimulating interest and dialogue" on the subject of future space exploration.

To tell his tale, Michael Smith—chief of marketing communications for the Space Systems Division—has put together a collection of seven articles by "Danielle K. McKinzie," communications specialist on this flight of the "Spirit of Galileo" Marsliner. The first essay, "The Journey Begins," tells how McKinzie qualified for a berth on the flight. "The Emigrants" describes the launch from "California's hot dry deserts to low Earth orbit," complete with offhanded references to the dependability of the "Convair 1100" transatmospheric shuttle—built by General

Dynamics, of course.

In successive articles, we see life on a lunar shuttle, get a tour of the Tranquility 4 Moon base, ("the largest, continuously inhabited extraterrestrial colony in the galaxy"), and visit "L-Port," the massive way-station/refueling depot/maintenance facility that is the jumping-off point for trips to Mars. After describing the actual Mars flight, Smith's tale concludes with a "personal account compiled by the author through interviews with settlers at Jamestown II, Mars."

Certainly most, if not all, of these ideas have been covered before. So what makes *The Emigrant Trail* special? Partly it's the uncanny sense of "you are there," which is provided not only by the text, but by the technical diagrams, sketches, drawings, paintings and photographs (the last showing how things were done in the Old Days of the 20th century). A very few top-drawer writers, such as Robert Heinlein, have the ability to write about the future and make it as real as the present. Put Michael Smith in this elite; he sustains credibility through every page of *The Emigrant Trail*.

Another bonus is that the book is written on several levels of complexity. An old space hand can read it without being bored, and the newcomer or youngster can follow the voyage without getting confused or lost.

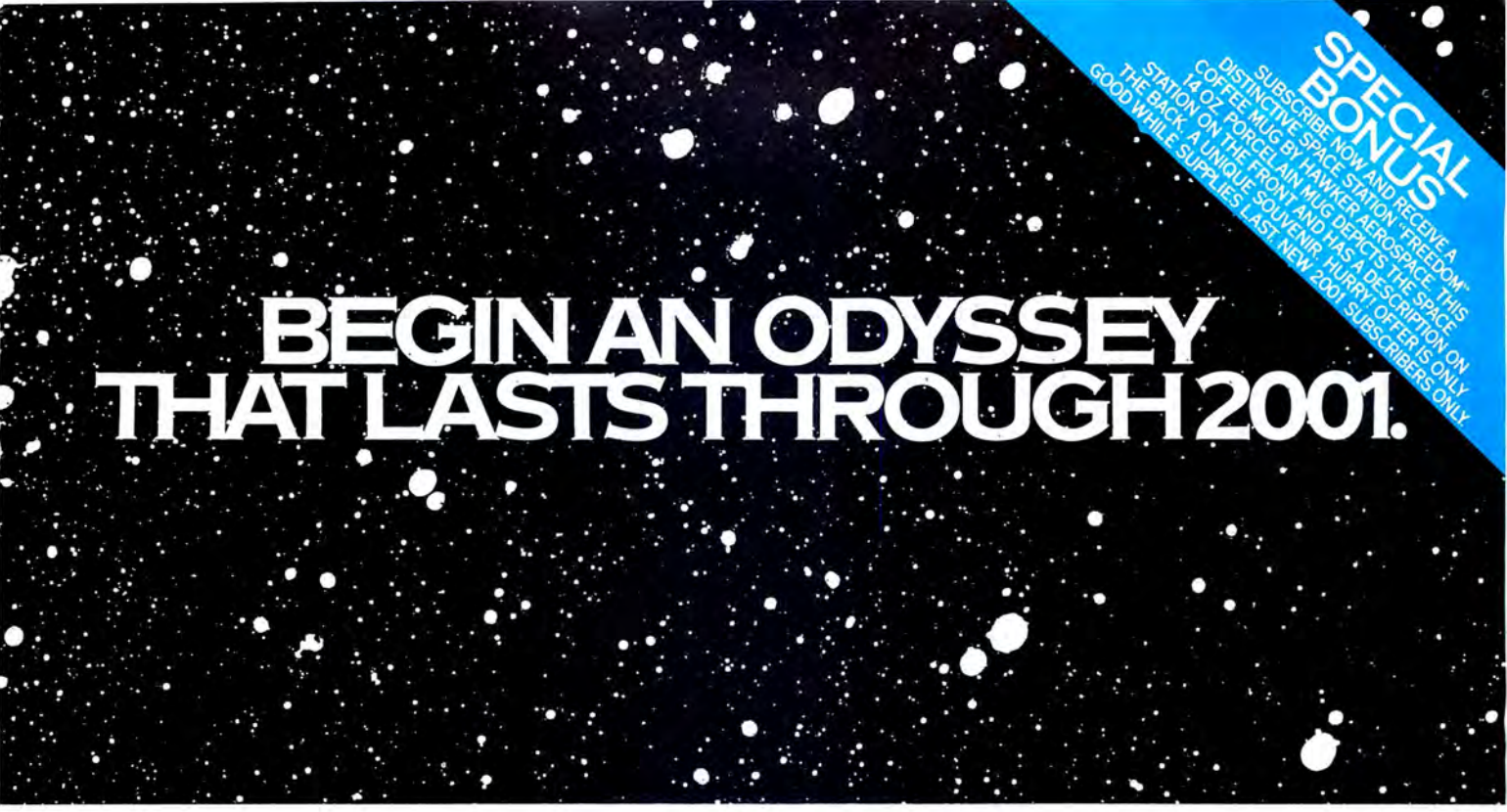
The Emigrant Trail makes the critically important point that a successful spacefaring civilization will not construct a Moonbase or L5-type colony as isolated projects, but rather as part of a complex "infrastructure." It's a vital concept. All too often, space exploration has been sold to the American public as a series of unrelated one-shot projects. Apollo, Skylab, the shuttle and even space station Freedom usually come across as random sticks floating downstream, rather than as rungs in a ladder that will take us to the stars.

Note, too, that Smith's vision of the spacefaring future is literally "for all mankind." His hardware comes from manufacturers as diverse as IBM, Mitsubishi and China's Great Wall Industries, and the Spirit of Galileo's crew is a polyglot assortment of nationalities, including a Soviet chief engineer who began his career with Glavkosmos, later worked under contract to the European Space Agency, and wound up with NASA.

As you might expect, the text repeatedly promotes General Dynamics, but it doesn't detract from the narrative. Smith simply makes you take it for granted. And it's refreshing to find a large aerospace company that not only takes the long view, but understands the importance of communicating that vision to the general public. Educators and space activists take note: General Dynamics offers reduced prices for bulk orders.

I can't think of another recent book that synthesizes the romantic excitement with the technological realities of space travel as well as this. On a scale of one to ten, *The Emigrant Trail* scores in double digits. □

Jack Kirwan is assistant editor of the University of Arizona's Energy Journal *and a frequent writer on the subject of space exploration.*



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High Cost

continued from page 23

twelve months. But the final award usually goes to just one bidder.

"In the case of the space shuttle main engine, we chose one contractor, and the other players more or less were sidelined," says Jerry Thomson, manager of the advanced propulsion office at NASA's Marshall Space Flight Center in Huntsville, Alabama. "Contractors can't compete very well when it's winner-take-all."

The Goddard Space Flight Center recently completed a competition between Grumman and Martin Marietta for the opportunity to build a Flight Telerobotic Servicer, a robot intended to help astronauts assemble and service the space station. Goddard engineers had come up with their own design of what they thought the robot should look like. In the early stages, the Grumman and Martin Marietta proposals both were different. During Phase B, Martin Marietta's design evolved into almost a duplicate of the Goddard design. The company won the nine-year, $303 million project, and Grumman was eliminated.

When so much is at stake, one solution is to retain at least two contractors to build competing hardware. Although duplicative, the increased competition could improve performance and lead to long-term cost savings.

In the early 1970s, for example, the Defense Department concluded that sophisticated but cheaper fighters were needed to complement the high-priced Navy F-14 and the Air Force F-15. In 1972 the "Lightweight Fighter" RFP was released to nine aerospace companies. It listed several goals, but few specifications, which gave contractors leeway in designing the project.

Five companies responded. From these, the government selected General Dynamics and Northrop to build prototypes for fly-off competitions. While General Dynamics' F-16 won the Air Force contract, eventually there was no "loser;" the Navy bought Northop's F/A-18 as a replacement for its aging attack jets. Both services got the planes they needed—from one head-to-head contest. The cost of these new aircraft was millions less per plane compared to the larger fighters; maintenance costs are about half; and the new planes deliver more performance.

Spacecraft, however, are often built one at a time rather than in quantity. So an alternative to awarding multiple contracts for a large project is to promote cost savings through friendly competition among a prime contractor

and several subcontractors. For its new ALS engine, NASA and the Air Force plan to select a single contractor who will be responsible for overall engine system management and integration. The prime contractor will then subcontract to competitors for manufacture of the engine's major subsystems. This should give the ALS program more leverage in negotiating a follow-on contract, according to NASA's Jerry Thomson. "It's our intent to keep these [different contractors] involved in a substantial portion of this engine," he said, "so that we have some alternatives when we go out to procure new buys."

Another possibility for saving money is the use of consortia. McDonnell Douglas, Rockwell International, General Dynamics and Pratt and Whitney, in a rare show of cooperation, recently joined forces to study advanced materials for building the National Aerospace Plane. A second NASP consortium is being formed for vehicle subsystems.

Forced to work together in this way, industry should perform well. Left to compete on its own, it fosters waste. Information is seldom shared in the aerospace community, which causes the same ground to be covered over and over, at the taxpayer's expense.

"Much of the really useful information ends up in somebody's file cabinet and never gets used again," said a manager with Honeywell's space and strategic avionics division. To prevent this, NASA has to demand that the information it pays for is made generally available.

But the role NASA plays in overseeing the aerospace industry has for some time been blurred by the undercurrents of self-interest. Bureaucracies by their nature tend to want their budgets to grow, and the space agency is no exception. Also, government managers who oversee multimillion dollar procurements often retire from public service to join the companies whose contracts they formerly supervised.

This "revolving door" led Congress last year to pass an ethics law restricting certain government officials as to the jobs they can take in private industry after retirement. The law, which took effect May 15, is meant to remove any temptation to allow cost overruns by a company that may become someone's future employer.

The law—and even the suggestion of impropriety—has rankled some at NASA. "People have dedicated their lives to this business, then all of a sudden they say that when you are done with your job, you have to go out and be a hardware store clerk," complains Holmes S. Moore, a senior program manager at the Center for Space and Advanced Technology in Arlington, Virginia.

Whether the law could eventually lower space program costs by making stricter watchdogs of government managers, it has wreaked havoc on NASA in the time being. Twenty-five senior managers left the agency in the weeks and months prior to the law's effective date. Many blamed, in part, ambiguities in the legislation. Among those who retired suddenly were James B. Odom, former associate administrator for the space station program; Howard Robbins, associate NASA administrator; and Noel Hinners, deputy NASA administrator. Hinners, who was highly regarded in his career as a civil servant, now works at Martin Marietta as a vice president for strategic planning.

While a good case can be made that problems inherent in the bureaucracy work against cost savings, only so much blame can be laid at NASA's door.

There is plenty left for Congress.

At a recent technical symposium on space station Freedom, representatives from Canada, Japan and the European Space Agency each got up to describe the funding mechanisms by which their respective governments would pay for the international project. All three had already received multi-year funding approval, ranging from two years up to the lifetime of the project. When it came his turn, William B. Lenoir, NASA's new associate administrator for the space station, could only joke that he was sorry his international partners were denied the "pleasure" of fighting for their budget each and every year.

That is the case for all NASA programs. The annual budget battle makes it difficult, if not impossible, to assign priorities and build a staff. When their budgets take a hit, managers face either killing a project or stretching out its completion. And whatever cost savings appear in that year's budget exist only on paper.

"You get cuts and you have to replan the program to fit the new funding profile," says David Bates, deputy director of the program control group at the space station office in Reston, Virginia. That means more delays, more work and more money.

The costs of the project's "infrastructure"—including all the salaries required to keep work teams in place—remain, eating up a higher percentage of the funds. Content suffers. Morale drops. Cost overruns mount. And the Congress, oblivious to the root causes, sees the price tag rising and threatens further cutbacks to an already underfunded program.

The cost of Congressional underfunding was outlined in a letter last May from Dale Myers, acting administrator of NASA, to Robert Traxler, chairman of the House subcommittee that handles the agency's appropriations. In his letter, Myers estimated that a Congressional proposal to delay $1 billion in funds earmarked for the space station would cause the project schedule to slip three months over the next year. More telling, the $1 billion deferment—$400 million in fiscal year 1990 and $600 million in the next—would cause inefficiencies amounting to an *additional* $1 billion beyond the deferment, which would have to be added onto the bill. The delay in funding, Myers predicted, "would be a disastrous mistake" that would "undermine the effectiveness of all that has been accomplished to date."

That Congress is schizophrenic about the space station is all too clear. In 1984, federal legislators passed a bill

requiring the agency to develop new automation and robotics technologies "not in use in existing spacecraft" for the station, and further mandated "that the development of such systems shall be estimated to cost no less than ten percent of the total space station costs."

But if Freedom is required to be an orbiting testbed for advanced technology, the costs will be high. And, considering that the station's international partners all have their own requirements and expectations, NASA has less and less flexibility in the size or cost of the project.

Ideally, the funding should be assured by the Congress that incurs the costs. But NASA cannot cry "foul" too loud. The agency needs to be liked by Congress, and that may be one of the biggest causes of inefficiency.

To attract political support, NASA seeks constituents in key Congressional districts. Projects like the space station try to appeal to different research communities, from materials scientists to astronomers. NASA works to modify the station to make everyone happy—a complex and costly effort that more often than not backfires.

"The irony is that if you start cutting out requirements, deliberately saying that you will not handle this need or that group, you run the risk of losing political support," explains Adam Gruen, a space station historian at NASA.

The same sort of dynamics are seen in the construction of space hardware. Work is distributed around the country to meet political rather than engineering goals. Building part of a vehicle in Seattle, part in Washington state and a third in Texas creates a logistical nightmare, adding time and expense to any project. But the jobs created in those different districts translate to political support in Congress, and give NASA another selling point for justifying growing expenditures.

Ultimately, the lack of political vision and the failure to follow through on existing commitments are the cause of this malaise. A report issued last January by the Commerce Department's Commercial Space Advisory Committee criticized the government for not having a stable national space policy. During the past 30 years, the report noted, the role of NASA in research and development has undergone seven major policy shifts.

Not since John Kennedy has an American leader embraced space exploration for the long term. The vision he had is as relevant today as it was when he spoke to the American public in the heat of the Cold War: "Now it is time to take longer strides, time for a

great new American enterprise, time for this nation to take a clearly leading role in space achievements, which in many ways may hold the key to our future on Earth."

If America is to continue to lead in space, bureaucrats, contractors and politicians will need to put the interests of the nation ahead of their own. Changing a system riddled with self-inflicted and entrenched inefficiencies will be difficult. But difficulty has not deterred Americans before. And change it must if the United States is to afford its dreams and reach its potential in space. □

Gary Stephenson and Greg Freiherr are information analysts with GFI, a consulting firm in the Washington, D.C. area. Along with GFI associate Miles Weiss, they interviewed dozens of people in NASA, Congress and the aerospace industry for this article.

ALS

continued from page 21

and shipped to a launch pad in California or Florida, where they are re-assembled and re-tested. Because Titans evolved from ICBMs — which are delivered to missile sites all over the country — there was originally no need to locate near any one site. And even after 30 years of space operations, no rocket manufacturer has moved its production facilities to be near the launch site.

"There are a lot of things that make sense that have never been done before," says Wormington.

Currently, rockets bound for polar orbits are launched from California, and rockets bound for equatorial orbits are launched from Florida. It is technically possible, however, for a vehicle to "dog-leg," as Wormington puts it, into a polar orbit from a Florida launch site. It normally isn't done, because the rocket's performance is poor. But if that could be offset by the savings of not building two separate launch sites, it may be worth it.

Even the method of getting space vehicles to the launch pad could be streamlined. NASA's "crawler" platforms were designed in the 1960s to keep huge Saturn 5 rockets upright and free from stress on their way to the pad. But if the ALS rocket were more rugged it could take more stress, and the crawler could be less sophisticated, says Wormington, adding that "the oil industry moves large objects around all the time."

This tendency to look outside the space community for answers is another ALS philosophy. "We're not proud," says Wormington. "We'll steal from anybody." Even the Soviets. When ALS engineers learned that the giant Energia vehicle uses "strap-on" rockets that are themselves stand-alone launch vehicles, they started looking at how common boosters might be used for the whole "family" of different-sized vehicles envisioned for ALS.

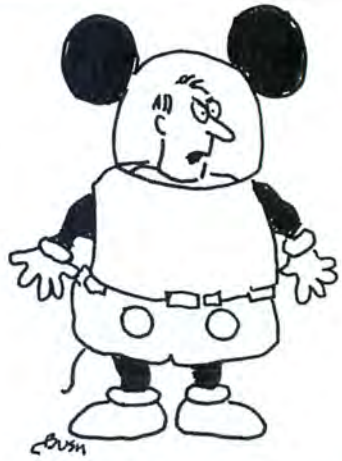
There are many trade-offs still to be made in creating what one Air Force official has called a "revolutionary" launch system. Recovering and re-using engines after a launch makes economic sense, for example, only if the engines are too expensive to throw away. But the goal — and perhaps the biggest technical challenge of the program — is to make them so cheap as to be expendable. In fact, says Wormington, "In the best of all possible worlds, I'd like to throw everything away."

Rather than simply talking about cost savings, ALS engineers are spending $1 billion on building prototype hardware. Eighty different subsystems, from nozzles to fuel tanks, will be produced by 1994, all with cost a primary factor. Rocket engine turbopumps, for example, now run $5 million each. The ALS task is to produce a prototype for half a million.

Wormington likes to use the word "robust" in describing his blue-collar rocket. He talks about how Conestoga wagons were pulled by oxen, not by horses. If the ALS program stays on track, the first test flight of his dream machine will be in 1998.

And after that? General Thomas Moorman, head of Air Force space programs, recently told a space conference in Washington that the ALS people could start building vehicles for "the first user with a need." □

— Tony Reichhardt



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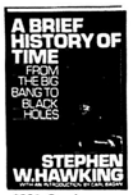

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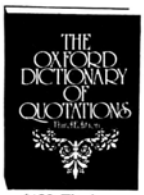

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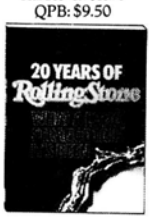

*716. From the pages of *Rolling Stone*, a documentary of the past 20 years.
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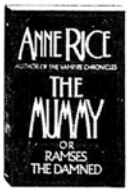
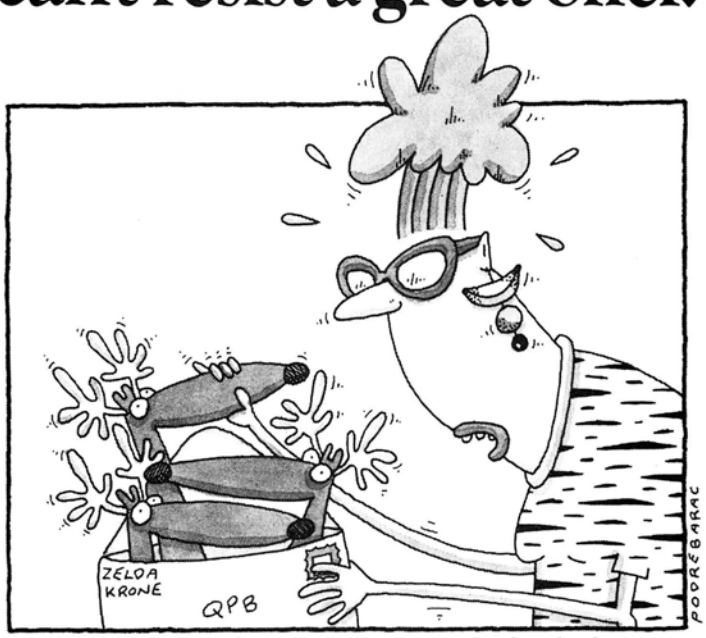
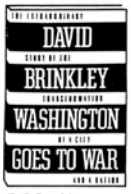


169. Fast-paced creepy fun from the author of the best-selling *Vampire Lestat*.
QPB: $9.95

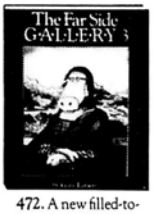


Choosing three books was easy, but getting the three bucks into the envelope proved to be beyond Zelda Krone's capabilities.

109. A special QPB trio: *The Elements of Style, The Elements of Grammar, The Elements of Editing.*
3-volume set
QPB: $10.95



547. Brinkley recreates the electrifying climate of Washington, DC. during W.W. II.
Hardcover: $18.95
QPB: $9.50



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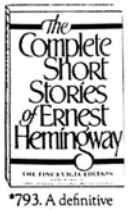

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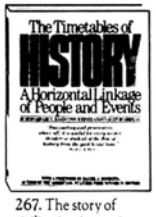

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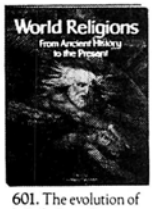
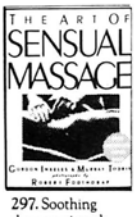
QPB: $15.95



601. The evolution of beliefs throughout history. Illustrated.
Hardcover: $29.95
QPB: $12.95



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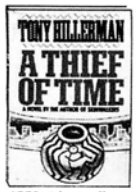
QPB: $9.50



*559. A best-selling novel set in the New Mexico desert.
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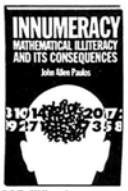

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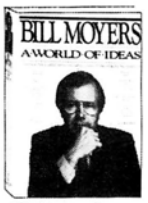

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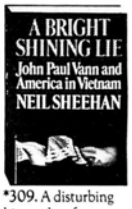

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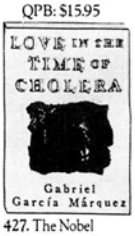

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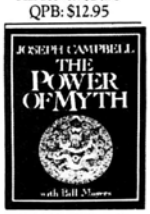

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Alan Bond

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duction would be far too great for the U.K. to contemplate on a national basis."

Of his homeland, Bond says bitterly, "They just junked a major opportunity to leapfrog into the 21st century. You don't get opportunities like that every day."

So Bond went looking for international partners for the multibillion dollar project. But even after he and British Aerospace succeeded in marshalling the support of a great many London investors—to the tune of $160 million—Rolls-Royce declined to join the consortium and it foundered.

Instead of enjoying the kudos of his countrymen while watching HOTOL take shape, Bond therefore found himself back at the drawing board, where he came up with a new engine design, named—innocently, he claims—"Satan." "He's just a powerful being from mythology whose name begins with 'S'," says the inventor. "It's a habit we have in Britain to name engines beginning with 'S.'

To block any government attempts to stifle his plan, Bond has intentionally neglected to patent the Satan design. If he were to patent it, the British government could slap a secrecy edict on the technology and prohibit the inventor from taking it abroad. Which is precisely where Bond is looking for a few adventurous investors. He says he needs only $16 million or so to fund the first three years of proof-of-concept testing, which he claims would help marshal the resources of investors, industry and governments to actually build a HOTOL spaceplane.

Such a vehicle could operate for as little as $2 million to $3 million a flight after the first couple of decades, Bond says. "HOTOL could go down as the first space vehicle to recover its development costs from commercial activities."

Some call him unrealistic. He describes himself as a "frustrated innovator," and says he won't give up. Bond has a vision shared by others with a fascination for the stars (in the 1970s he designed another vehicle named for a mythical figure— the "Daedalus" starship). He fears the world ecosphere has reached the point where perhaps only 100 years are left before the survival of humanity will be threatened.

"Meanwhile, we're surrounded by the most incredible resources. We could take the resources of the Solar System, divide them on a per-capita basis, and all be incredibly wealthy.

"We just don't have a bus ticket to get there," says the inventor. "All I'm trying to do is build the bus."

Frederic d'Allest

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on 1988 sales of about $600 million. That's in addition to reserves and retained earnings of $90 million, and set-asides of $132 million to cover the risks of operating in such an inherently risky business.

There have been some Ariane failures, too, but Arianespace has learned from its mistakes and from the Challenger accident. According to d'Allest, the warnings of the Rogers Commission made him enact more vigilant controls on his suppliers and increased his concern for the morale of the workers at Kourou.

Since 1984, Arianespace has invested $200 million to improve its

launch vehicles. The company last year demonstrated a commitment to keep costs down by ordering 50 of the latest version (Ariane 4), worth $2.6 billion. Ariane 4's most powerful variant flew for the first time in June; it carried two satellites, one of which—the Japanese Superbird—was the heaviest commercial satellite ever made.

Arianespace has demonstrated its success by picking up more than 50% of the world's launch business in the face of increasingly stiff competition by U.S. commercial launchers, the Soviets and the Chinese. D'Allest has been there from the beginning, making the tough choices: as Ariane project manager for the French space agency CNES; as director of the Ariane program in 1976; and as the company's first chairman and CEO in March 1980, when Arianespace was created as a consortium of European aerospace companies and financial institutions.

During much of the last decade, from 1982 until February of this year, he was also director general of CNES. Asked whether he considers himself a bureaucrat or a businessman, d'Allest says he prefers the latter, and he describes with relish his latest challenge—to make Locstar, the European counterpart of Geostar (see p. 34), "number one in this market."

As 1992 and the unification of the European marketplace near, d'Allest believes Arianespace won't feel any effects, having paved the way for international commercial collaborations on a grand scale. D'Allest also says he considers it "a matter of political will for Europe to be a space power by the end of the century." As the man who presided over CNES's budget while planning for the next decade in space, he's confident Europe's goals are achievable.

If past performance is a barometer, you're inclined to believe Papa.

Alexander Dunayev

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prestigious post. After he rose from obscurity in the fall of 1986 to head the new Glavkosmos agency, Soviet sources said only that Dunayev has held "a number of senior positions" within the bureaucracy, or that he was an engineer in the Soviet aerospace community. The Novosti Press Agency doesn't even stock a biography.

In the absence of such basic background information, dark tales have circulated in the West about his highly-placed political connections. That line of reasoning stems in part from his evident disdain for the Soviet Union's scientific space community, demonstrated publicly at the Space Future Forum commemorating the 20th anniversary of Sputnik in October 1987. A very senior Soviet academician was delivering a paper to the assembled international guests when Dunayev suddenly said, "I don't think our audience is interested in that right now," and told the scientist to sit down.

He sat down.

Dunayev's abrasiveness hasn't made him many friends in the Soviet space establishment; Roald Sagdeyev of the Institute for Space Research has used the word "odious" to describe him on at least three separate, very public occasions. And recently, the Institute blamed Glavkosmos for the failure of the two Fobos spacecraft, which the marketing agency designed with very little supervision from scientists.

Increasingly, the very policies of *perestroika* and *glasnost* that created Glavkosmos are putting pressure on Dunayev to deliver on the promise that space can pay its own way in the struggling Soviet economy. He may have to prove that he's a successful marketer, not just a shopkeeper who stocks an impressive array of wares. The Glavkosmos czar admits that the agency has netted a mere $600,000 for all its efforts at commercialization.

Dunayev likely won't have smooth sailing. The United States shows no sign of relaxing limitations on technology transfer that prohibit shipment of satellites with made-in-the-USA components to Soviet launch sites, despite Dunayev's assurances that his Glavkosmos workers won't even open the sealed containers. But ever optimistic, Dunayev has hired an American marketing firm, Space Commerce Corporation of Houston, Texas, and compiled a catalog of available Glavkosmos services that was distributed at the Paris Air Show last June. Not many prices appeared, though.

"Make me an offer," says Dunayev.

Byron Lichtenberg

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approved quietly by the Commerce Department in February of last year. A few in Washington—notably then-Transportation Secretary James Burnley—blasted the accord as downright un-American, but Lichtenberg defended it, arguing that the agreement is in keeping with the increasingly international nature of space.

"The Soviets are really marketing aggressively, and they're open to virtually any idea," says Payload Systems' chief scientist. "Our cooperation with them has been a learning experience on both sides."

Among the blips in the learning curve was the time Lichtenberg learned from press reports that the Soviets were planning to have their space station in mothballs during the time of Payload Systems' planned mission. The flight has been rescheduled for October.

Lichtenberg maintains that the delays and bureaucratic hassles are worth it, because there is no comparable U.S. opportunity for long-duration microgravity. Even the shuttle's seven- to ten-day flights aren't long enough for some proteins to form large, well-ordered crystals. And NASA's space station is still years away.

"Companies and countries around the world are not sitting back waiting for NASA to get its act together," he says. "They see that the Soviets have launch and on-orbit capability, and they're going for it."

It is Lichtenberg's vision to act as an intermediary, helping other researchers see what space can offer. But, he adds, "I don't want to watch, I want to do it." In fact, he's now training to "do it" for the second time in 1991, when he'll fly on the first shuttle Atmospheric Laboratory and Application Series mission ATLAS-1. Lichtenberg's distaste for bureaucracy led him to resign as president of Payload Systems earlier this year and pass the baton to Arrott.

But he expects to be around in 10 to 15 years to see the company operating tours of the Moon and other orbital outposts. To that end, Payload Systems plans to buy its own aircraft soon to offer the general public the same taste of weightlessness that NASA astronauts experience in the KC-135. The search for capital to finance that project led the company to merge with Space Industries Inc. earlier this year.

"We have to start small, but we have big dreams," Lichtenberg says.

Martin Rothblatt

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Carriers and the Santa Fe Railroad, which all use the position-finding service to track vehicles.

The company's technological future also looks bright. Sony and Hughes Network Systems, Geostar's ground equipment suppliers, have developed the world's smallest satellite dish, an antenna measuring just six inches in diameter. And Motorola has produced 15 prototypes of the hand-held transceiver that Rothblatt hopes one day will be the equivalent of *Star Trek's*, flip-open communicator.

In addition, Geostar is licensing its technology abroad, spawning a European company called Locstar, which will serve Europe, the Middle East and North Africa, and another firm in Australia aimed at the Pacific Rim market.

All of that is good news to O'Neill, who donated 85 percent of his Geostar shares to the Space Studies Institute—a stake already worth $22 million. On the strength of that endowment, SSI this summer launched a plan to privately procure a small lunar probe to gather information vital to the success of a future lunar colony.

And it's good news to Rothblatt. "When I was in college and people asked me what I wanted to be, I said, 'a space entrepreneur,'" recalls the 34-year-old Geostar president. "Now I am one—and it's even better than I'd imagined."

David Thompson

continued from page 35

bers. "When I left [in 1979] it was *still* two years away. I wanted things to move a little faster."

For Thompson, they certainly did. At Harvard Business School, he met future partner Scott Webster on the first day of class. In their second year they obtained a NASA grant to explore how government could make it easier for private space companies to form and prosper. By then the pair had attracted Harvard law student Bruce Ferguson, who remains the OSC counsel.

The trio originally conceived a space company that would rescue empty shuttle fuel tanks and use them in orbit as floating fueling stations. ("It's still not so hot an idea," Thompson says now.) Instead, the group settled on a redesigned Centaur upper-stage booster rocket they called the Transfer Orbit Stage, or TOS.

Thompson and his crew initially raised more than $13 million from various sources. Then in 1983, with the help of what was then Shearson/American Express, Orbital Sciences hit the jackpot with a $50 million research-and-development partnership—the sixth largest ever placed at that time, and the largest ever in the aerospace industry.

Martin Marietta contracted to build the TOS, but it wasn't for three years, until March 1986, that NASA agreed to purchase the rocket for the agency's Mars Observer spacecraft. Sensibly, OSC had designed TOS with the shuttle in mind. After the Challenger disaster, however, the space agency had to kick almost all commercial satellite launches off the shuttle, cutting OSC's potential market by a third.

Adapting TOS for use with the Titan (Mars Observer's eventual booster-of-

choice) more than doubled the stage's $31 million price. But OSC still did all the development work on the project for around $80 million—a fraction of the billion-dollar boondoggle that the Air Force's Inertial Upper Stage became.

Like NASA, Thompson learned not to hitch his wagon only to the shuttle. Last year, OSC announced a joint venture with Hercules Aerospace to build the Pegasus satellite booster, air-launched by a NASA-owned B-52, and signed up the Defense Advanced Research Projects Agency (DARPA) as the rocket's first customer.

To become profitable for OSC, Pegasus must attract commercial users as well. Ball Aerospace inked a launch agreement last June for a series of rides for its new lightweight satellite series. If Ball finds customers, and OSC wins more contracts to fly them, the rocket will work off its development costs in record time.

The future looks bright. OSC has doubled and tripled in size in the last two years, and may go public as early as October. The company continued to diversify in autumn 1988, buying Space Data of Tempe, Arizona, a company that makes suborbital boosters, space system hardware and associated electronics and data systems.

But Thompson says OSC won't become just another aerospace giant. The company's goal is to drive down the cost of access to space. Until business can afford space, he argues, it will be the province of government alone.

And government can't afford enough of a space program to suit Thompson. □

Contributing editor Melinda Gipson is the editor of Space Business News, *a biweekly newsletter published in Arlington, Virginia.*

Off the Shelf

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and take pride in helping the space program by developing space equipment at their own cost. Coke and Pepsi got enormous publicity from developing soda cans for space. Unfortunately, they weren't very practical for the space environment despite the enthusiasm of the two giant competitors. "Eight cans of soda took up the same amount of space as 128 dry beverages," says Fohey. Now Coca Cola has worked out a commercial agreement with NASA to develop a system for dispensing liquids on the space station.

Naturally, the main advantage to using off-the-shelf items in the space program is lower cost. The bargain-basement approach can backfire, however, if a manufacturer has to alter materials and methods to suit NASA. Costs escalate, and the space agency has to buy enormous quantities to realize a savings. NASA once purchased 100,000 rugged plastic food pouches, only to have two-thirds of them degrade during long storage.

Nonetheless, most crew systems engineers agree that the cost of testing, adapting and modifying off-the-shelf equipment almost always is much less than developing the product from start to finish. And cost isn't the only advantage; familiar items are psychologically easier to use in space.

Still, there are some disadvantages to store-bought products. Models and parts change, and even the technology itself changes. Sometimes the product itself is a lemon. Often a wonderful gadget disappears from the market unexpectedly, so that NASA can't always depend on its availability.

Commercially available electronics also don't meet rugged specifications for long-term reliability, durability and wear. "In essence, we have the same problem as the ordinary consumer," said Max Engert of the Johnson Space Center. "We don't have a service history of reliability, the design of the components isn't documented and the products aren't designed for the long haul."

Space station Freedom almost certainly will incorporate a variety of off-the-shelf hardware, rendering the alien space environment more familiar, more livable and more endurable. For example, a microwave clothes-dryer currently under development for the consumer market has NASA engineers excited. Similarly, an automatic bread-baker may find its way into the space station galley, although the commercial machines now available are still much too gravity-dependent to be practical in space.

But even in space, there will be a few hold-outs against the trend toward convenience. Consider the perfect cup of coffee. Astronaut Franklin Chang-Diaz, a naturalized American from Costa Rica, considers drinking instant coffee "a sin." So he designed an infusion/extraction zero-gravity coffeemaker to enjoy the perfect pleasure of a brewed cup of coffee in space....

Even if he does have to drink it through a straw. □

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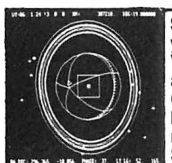

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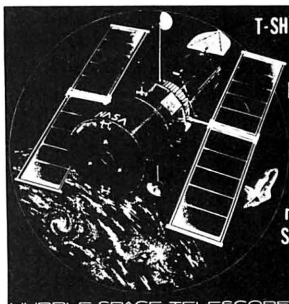

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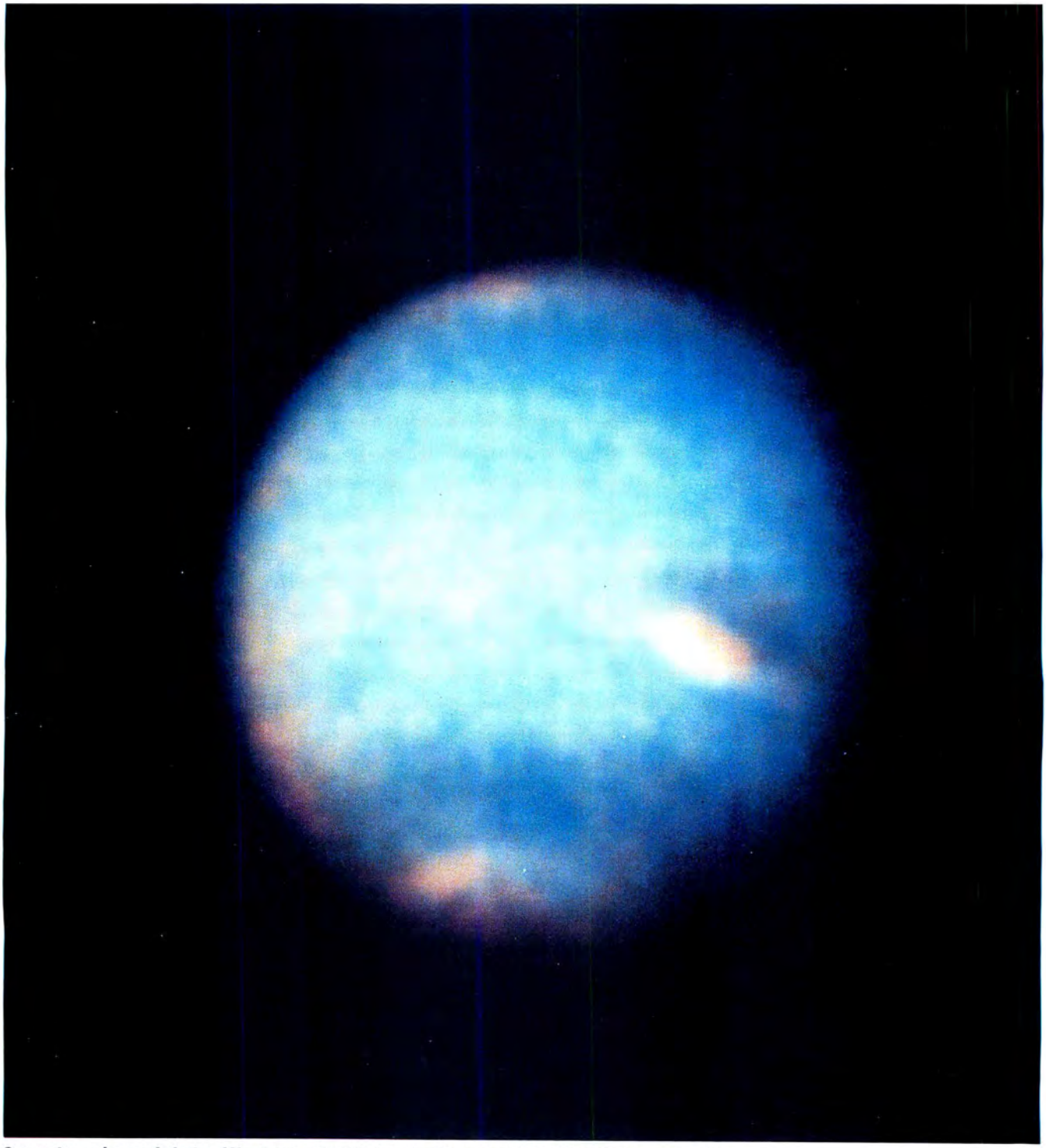
Then felt I like some watcher of the skies
When a new planet swims into his ken.

John Keats



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